URINE, URINARY DEPOSITS,

AND

CALCULI,

AND ON THE TREATMENT OF URINARY DISEASES.

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WITH NUMEROUS ILLUSTRATIONS, AND TABLES FOR THE CLINICAL EXAMINATION OF URINE.

BY

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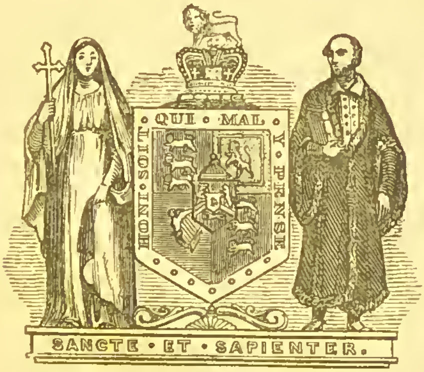
SECOND EDITION.



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DEDICATED TO THOSE WHO

WORKED WITH THE AUTHOR IN HIS LABORATORY,

AND AT A VERY EARLY PERIOD OF HIS CAREER

GAVE HIM THE

WARMEST ENCOURAGEMENT AND SUPPORT.

1852.

PREFACE

TO

THE SECOND EDITION.

The Author has endeavoured to increase the usefulness of the Work by the addition of observations on the treatment of urinary diseases. Experience has taught him that the treatment of many chronic and obstinate diseases of this class is more successfully carried out by attention to the general physiological changes going on in the system, and by the use of *simple* remedies in suitable doses, given regularly, and persevered with for a considerable time, than by the employment and frequent change of complex formulæ. In common with many physicians, the Author feels that the treatment of disease may now be conducted upon well recognised and intelligible principles, and that the system of ordering a number of different substances should be deprecated, because evidence has proved it to be useless to the patient, whilst it must foster mystery in connexion with our art, and greatly retard the advance of medicine. The reader will, therefore, not find a list of all the drugs that have been advocated as having a special influence on the urinary organs; nor will he meet with complex recipes containing several different ingredients, the action of which is very imperfectly understood.

The general arrangement of the urinary deposits adopted in the first edition has been retained, as increased experience in teaching has convinced the author of its real practical utility. If the reader will refer to the arrangement of the contents in page xi., he will readily find any subject he requires. In addition, however, a copious index has been made. New observations and several new figures have been introduced, and a considerable part of the work has been entirely re-written, while new matter, to the extent of nearly 100 pages, has been added.

For the sake of convenience, and for cheapness, the work has been published in the form of a Hand-book, but it contains much original matter, and the results of greater labour than the reader would be led to suppose from a superficial review of the contents.

61, Grosvenor Street, W.,
October 1st, 1863.

PREFACE

TO

THE FIRST EDITION.

THE Lectures which are now published were first given in November, 1852, at a laboratory adjoining King's College Hospital (27, Carey Street, Lincoln's Inn Fields), which I had arranged for the study of those branches of chemistry and microscopical inquiry which have a special bearing on medicine. Several courses of lectures and demonstrations were given during the seven succeeding years; but of late, increased work in other departments has prevented me from devoting so much of my time to this branch of teaching.

The course on urine included oral lectures and practical demonstrations, in which every pupil performed the experiments with his own hands, according to the directions given in the Tables, which will be found at page 411 of the present work.

The lectures were first published in the *British Medical Journal*, and are now printed in a collected form, with several additions. I have endeavoured to restrict myself, as far as possible, to those parts of the subject which are of practical importance in investigating the nature of a case. It must be borne in mind that the Lectures were given to practitioners, most of whom had far larger experience in practice than myself. Little advantage, therefore, could have resulted under these circumstances from discussing special questions connected with the treatment of disease, and almost the whole time was devoted to the practical examination of

the urine and urinary deposits by the microscope, and by applying the appropriate tests. I have thought it right to retain this character in the present work, and only a few very general remarks will be found with reference to the treatment of urinary diseases.

I have had frequent occasion to refer to numerous works, and have inserted many references in the text between brackets. The names of almost all the authors consulted will also be found in the index.

Nearly all the analyses have been made by myself, and the drawings have in most cases been copied by me on the blocks, which were afterwards engraved. Those illustrating the chapter on the kidney have been very recently copied from specimens carefully prepared. Only comparatively few illustrations of the salts of the urine and of urinary deposits will be found in this work, as they have been already published in the "*Illustrations*," to which frequent references will be found. I have endeavoured, as far as possible, to give accurate copies of the objects; and almost all the drawings have been traced directly on the wood-blocks or lithographic stones. Each object has been represented of the exact size it appeared. The magnifying power is given, and a scale appended, by which anyone can measure each object.

References to different parts of the work are inserted where required, especially in the Tables at the end of the volume. Pains have been taken to arrange the subjects to be discussed in the most convenient manner. A glance at the arrangement which immediately follows will at once give the reader an idea of the contents of the book, and the order in which the subjects are treated of.

LIONEL S. BEALE.

61, GROSVENOR STREET, W.,
March, 1861.

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ORIGINAL ANALYSES OF URINE.

CHAPTER I.

Tests.—Chemical Apparatus and Instruments necessary for the Clinical Examination of Urine. *Balance—Weights, Test-tubes—Test-tube Holder—Small Retort Stand—Tripods and Wire Triangles—Spirit-lamp—Platinum Capsules—Water-bath—Beakers—Conical Glasses—Evaporating-basins—Wash-bottle—Glass Funnels—Filtering-paper—Glass Measures—Stirring-rods—Test-papers—Thermometer—Blowpipe—Pipettes—Urinometers and Specific Gravity Bottles—Clinical Pocket Microscope—Object Glasses—Microscope Lamp—Glass Slides—Thin Glass—Watch Glasses—Glass Cells—Brass Forceps—Stage Micrometer—Neutral-tint Glass Reflector—Bottles, with capillary orifices.*

For the general clinical investigation of urine, the practitioner requires certain tests and apparatus for performing chemical analysis, and instruments for examining urinary deposits by the microscope. I purpose, in the present chapter, to refer briefly to those instruments and pieces of apparatus I have found most necessary, inexpensive, and useful. These can be readily obtained of most instrument makers.

Tests and Chemical Apparatus.

1. **Tests.**—The principal reagents required for qualitative and quantitative analysis of the urine are enumerated below. They should be kept in stoppered bottles, of from two to four ounces' capacity. The strength of the solution required varies somewhat in different test solutions; but from ten to fifty grains of the salts may be dissolved in each ounce of distilled water. Distilled water

should be kept in a quart bottle; and it will be convenient to keep one of the wash-bottles represented in Fig. 10, Plate II., also filled with distilled water.

		Strength.
Alcohol	HO,C^4H^5O	Sp. gr. 0·83
Sulphuric Acid	HO,SO^3	Sp. gr. 1·84
Hydrochloric Acid	HCl	Sp. gr. 1·20
Nitric Acid	HO,NO^5	Sp. gr. 1·20
Oxalic Acid	C^2O^3,HO	50 grs. to 1 oz.
Acetic Acid	HO,C^4H^3,O^3	Pharmacopœia.
Ammonia	NH^3	Sp. gr. 0·88
Oxalate of Ammonia	NH^4O,C^2O^3+Aq	80 grs. to 1 oz.
Potash	KO	Sp. gr. 1·060
Ferrocyanide of Potassium	$K^2,FeCy^3+3Aq$	25 grs. to 1 oz.
Chloride of Ammonium	NH^4Cl	50 grs. to 1 oz.
Lime Water	CaO,HO	Sat. sol.
Carbonate of Soda	NaO,CO^2+10Aq	160 grs. to 1 oz.
Phosphate of Soda	$2NaO,HO,PO^5+24Aq$	50 grs. to 1 oz.
Chloride of Calcium	$CaCl$	50 grs. to 1 oz.
Chloride of Barium	$BaCl$	50 grs. to 1 oz.
Perchloride of Iron	Fe^2Cl^3	100 grs. to 1 oz.
Sulphate of Copper	CuO,SO^3+Aq	50 grs. to 1 oz.
Nitrate of Silver	AgO,NO^5	25 grs. to 1 oz.
Bichloride of Mercury	$HgCl^2$	25 grs. to 1 oz.
Bichloride of Platinum	$PtCl^2$	Sold in solution.

Fehling's Solution.—For mode of preparation, *see* § 47.

2. **Balance.**—A very efficient balance, which weighs to the 1-50th of a grain, and bears 1,000 grains in each scale, and is adapted for the quantitative examination of urine and other animal fluids and solids, may be obtained of Mr. Becker, of the firm of Elliott Brothers, Strand, for the sum of £3.

3. **Weights.**—It is desirable to be provided with *gramme*, and also with *grain* weights. These are furnished with the scales.

4. **Test-tubes**, of various sizes, will be required. The observer should also be furnished with the rack and drainer represented in Plate I., Fig. 1.

Fig. 1.

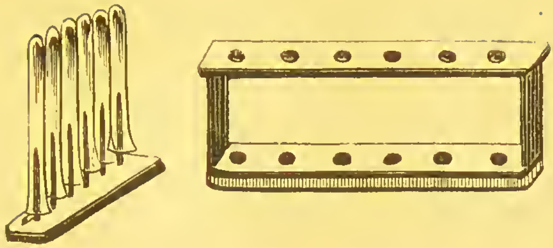

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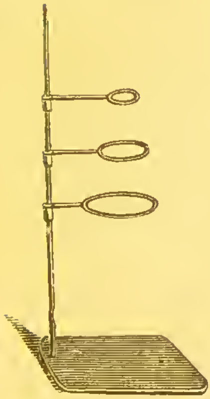
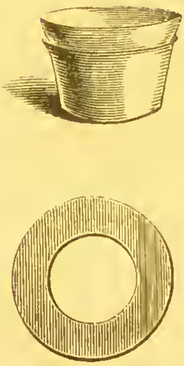
Fig. 2.



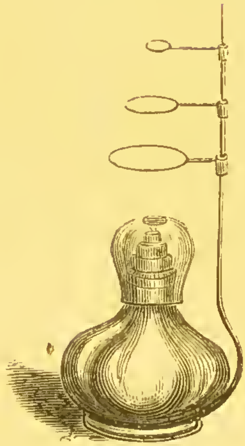
§ 6.

Fig. 3.



§ 10.

Fig. 4.



§ 5.

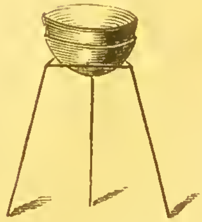
Fig. 6.
a

Fig. 7.
b

Fig. 5.

7

Fig. 8.



§ 7.

§§ 12, 23.

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5. **Test-tube Holder.**—A very simple form is represented in Plate II., Fig. 11.

6. **Small Retort Stand**, as seen in Plate I., Fig. 2 ; or attached to the spirit-lamp, as in Fig. 4.

7. **Tripods and Wire Triangles**, for supporting platinum capsules or foil, while the organic matter is being burned off. Plate I., Figs. 5, 8.

8. **Spirit-lamp.** — The ordinary glass spirit-lamp is the most convenient form.

9. **Small Platinum Capsule and Platinum Foil.** — A capsule about two inches in diameter will be large enough. This can be purchased for 12*s.* or 14*s.* It should be exposed to the clear smokeless flame of a spirit-lamp, or to that obtained by burning coal gas mixed with air, as it issues through fine wire gauze, or from a small conical tube placed over the gas-burner. Care must be taken that no lead or pewter comes into contact with the platinum when heated, or it will be instantly destroyed.

10. **Water-bath.** — A very simple form of water-bath is represented in Plate I., Fig. 3; or a small saucepan may be used. But when the observer desires to make many careful analyses of urine, he should be provided with a larger water-bath, so that four or five basins may be placed over it at one time. Several rings, of various sizes, cut out of thin sheet copper, will be required to support basins of different sizes over the water-bath. A little hot-water drying-oven is necessary for careful quantitative determinations. The injecting-can ("*The Microscope in Medicine*," page 25, fig. 59) may also be used as a water-bath.

The porcelain basins with residues, which have been dried over the water-bath, should be allowed to cool before being weighed. The observer will find it useful to have two or three glass shades, about 9 inches in diameter, with shallow glass dishes, for containing strong sulphuric acid, about four or five inches in diameter. Upon the glass dish, about half filled with the sulphuric acid, is placed a piece of wire gauze, or perforated zinc, to support the basins. In this manner the residues may be allowed to cool, without absorbing water, and they may be kept dry for some time, if requisite.

11. Two or Three Nests of Beakers.*

12. Conical Glasses, of the form represented in Plate I., Figs. 6, 7, or in Plate II., Fig. 9. The former combines the glass for the urinometer with a conical glass for collecting urinary deposits. This is a most useful form of conical glass. It was devised by Dr. Budd.

13. Porcelain Evaporating-basins, of various sizes, from eight ounces to half an ounce capacity.

14. Wash-bottle, for washing precipitates on filters (Plate II., Fig. 10).

15. Glass Funnels, of various sizes (Plate III., Fig. 13).

16. Filtering-paper, which can be purchased of the instrument makers, or of most stationers, under the name of white blotting-paper. The mode of folding filtering-papers is represented in Plate II., Fig. 12, or they may be purchased, ready cut in circles, of the operative chemists.

17. Glass Measures.—One pint measure, one 4-ounce, one 1-ounce, 1,000-grain measure, cubic inch measure. The cubic centimeter measures are described in Chapter II., on "*The Volumetric Analysis of Urine.*"

18. Stirring-rods.—These are made of ordinary glass rod, rounded at each end in the blowpipe flame; or of pieces of glass tube, the ends of which are drawn off and closed in the flame of the spirit-lamp or blowpipe.

19. Test-papers.—Blue litmus and reddened litmus.

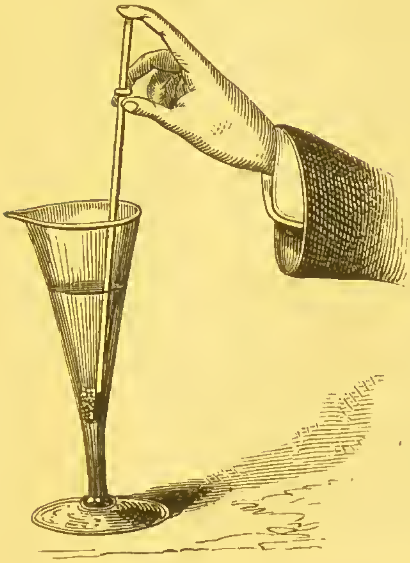
20. Thermometer.

21. Blowpipe.— An ordinary gas-fitter's blowpipe, which costs 6*d*., answers every purpose.

22. Pipettes, of two or three sizes (Plate III., Fig. 14*a*, *b*).

* Glass and porcelain apparatus may be obtained of Messrs. Powell, of the Whitefriars Glass Works, or they will be furnished by the instrument makers.

Fig. 9.



§ 12.

Fig. 10.

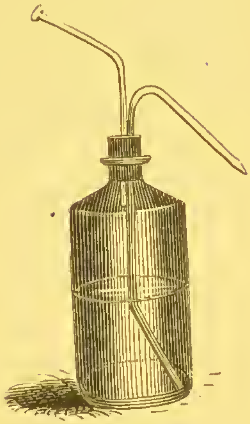


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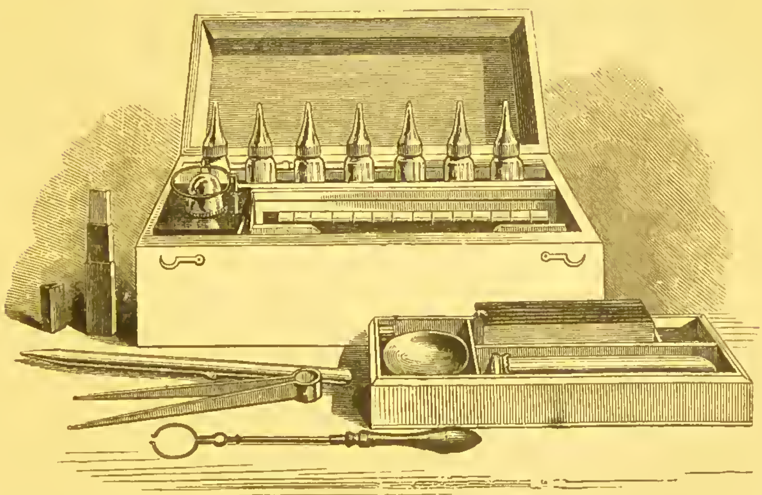
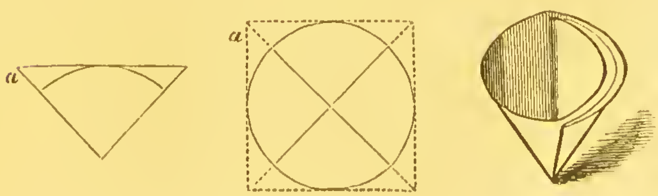
Fig. 11.



§§ 5, 34.

Fig. 12.



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23. **Urinometers—Specific Gravity Bottles**, for taking the specific gravity of urine. The specific gravity of a fluid is obtained most correctly by ascertaining the weight of equal bulks of the fluid to be examined, and distilled water. For this purpose, a small bottle, with a tubular stopper, holding exactly 1,000 or 500 grains of distilled water, at a temperature of 60°, is the most convenient form of apparatus (Plate III., Fig. 16). All that is necessary is to fill the bottle carefully with the urine, wipe it dry, and then weigh it, after having counterpoised the bottle. The number of grains which the fluid weighs is the specific gravity in the case of the 1,000-grain bottle, double the weight for the 500-grain bottle, four times the weight for a bottle holding 250 grains, and so on, in like proportion.

This method, although perfectly exact, and readily performed where a good balance is at hand, is nevertheless too tedious and troublesome for the practitioner in a general way, and, in the sick-wards, a much simpler, though less correct method, is usually resorted to. The specific gravity is obtained by a small hydrometer, usually termed a *urinometer*. The form of this instrument, and the mode of using it, are well known; but there are one or two points in its construction and management which it may be well for me to refer to. As sold, these instruments are often nearly useless, in consequence of the carelessness displayed in their manufacture. Out of twenty instruments, I have found several differing as much as ten degrees from each other. If the stem of many urinometers be examined, it will be found that all the degrees marked upon it are equal, which clearly ought not to be the case (Plate III., Fig. 15*a*); for when fluids of low specific gravity are operated on, a very small portion of the stem remains above the surface of the liquid (Plate I., Fig. 6*b*), while the reverse holds with respect to liquids of great density. In the latter case, there is, of course, a much greater weight of stem above the liquid, tending to force the instrument lower in the fluid than in the former (Plate I., Fig. 6*a*). Allowance must also be made for the fact that the fluid becomes denser as we pass from the upper to the lower strata.* The tendency of the instrument to indicate a higher density than the real one, renders it necessary that the degrees should *decrease* in length from the upper towards the lower part of the stem. The practitioner should carefully examine

* This error has been corrected by Mr. Ackland, of Messrs. Horne and Thornthwaite's, where accurately graduated instruments may be obtained.

his urinometer, to see that there is this difference in the degrees (Plate III., Fig. 15*b*), and if not, it should be changed. I strongly recommend everyone to test the urinometer by immersing it in fluids, the specific gravity of which has been ascertained by the bottle, or by a well made and previously corrected urinometer. If the degrees are incorrect, the observer can always bear in mind the amount of error, and allow for it in taking the specific gravity of different specimens of urine. The vessel which is employed for receiving the urinometer should not be too narrow, in case the bulb should rub against the sides, when it becomes difficult to ascertain the real density. Its diameter should be rather more than a quarter of an inch over that of the widest part of the bulb of the urinometer. The glass delineated in Plate I., Fig. 6, is a very convenient form.

Another method of taking the specific gravity, which is sometimes followed, consists in having a number of small glass bulbs, with the density of the fluids in which they neither sink nor swim marked upon them. By placing one after another in the urine, one is found which remains just beneath the surface, and the number upon it indicates the specific gravity of the fluid.

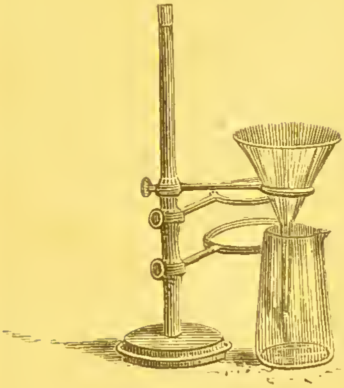
⁂ The chemical apparatus required for the analysis of urine will be provided by Messrs. Bullock & Reynolds, 3, Hanover Street, W.; Messrs. Griffin, Bunhill Row, E.C.; and other Operative Chemists; or they will be procured for the practitioner by most of the Instrument Makers.

Apparatus required for the Microscopical Examination of Urinary Deposits.

24. **Clinical Pocket Microscope.**—This is a very simple and inexpensive instrument, which I have lately arranged for the microscopic examination of urinary deposits and other substances. It may be used as a field microscope, and will be found a most useful form of instrument for the practitioner. When closed, it is only six inches in length, but when arranged for examination, the tube is drawn out as long as that in the ordinary microscope. Any powers can be adapted to it; and direct light, or light reflected from a mirror, may be employed. I have now used this instrument for some time for teaching in the wards, and find that it answers its purpose well. It may be fitted up with mirror, pipettes, slides and cells, in a leathern case. The instrument is made by Mr. Highley, 70, Dean Street;

CHEMICAL AND MICROSCOPICAL APPARATUS. PLATE III.

Fig. 13

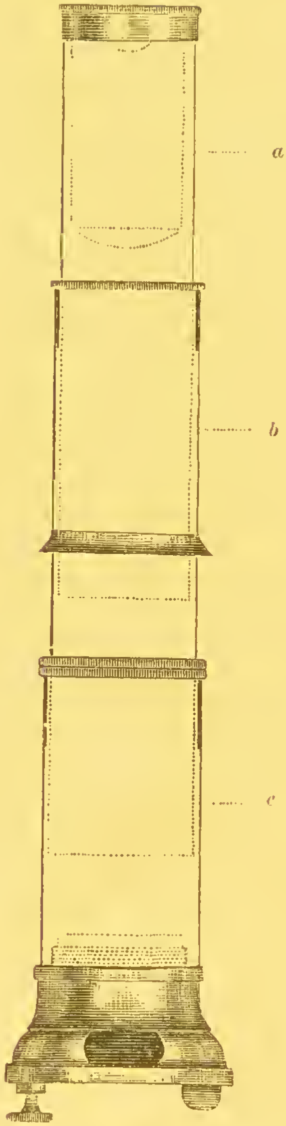


§ 15.

Fig. 14.

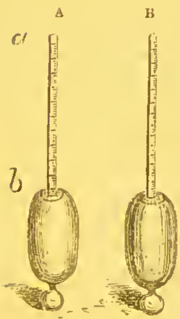
§ 22.

Fig. 17.



§ 24.

Fig. 15.

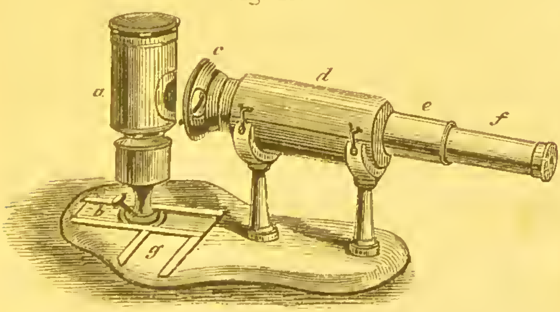


§ 23.

Fig. 16.

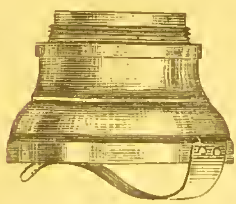
§ 23.

Fig. 18.



§ 24

Fig. 19.



§ 24.

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Messrs. Powell & Lealand, 170, Euston Road; Mr. Salmon, 100, Fenchurch Street; and by Mr. Matthews, Portugal Street, Lincoln's Inn. The clinical microscope is represented in Plate III., Fig. 17. It costs, with the eye-piece, but without object glasses, 25*s.* The arrangement of the spring, by which the preparation is kept in contact with the stage, while every part of the field is examined, is represented in Fig. 19. I have had this instrument fitted to a small stand, with a lamp for use by night, and a mirror for day, so that it can be very easily handed round in a lecture-room. I find this arrangement most convenient for demonstrating objects to large classes. The stand, with the clinical microscope, is represented in Plate III., Fig. 18. It is convenient also to be provided with a simple student's microscope, with large stage. (*See* the "*Microscope in Medicine.*") The tube of an ordinary microscope can easily be made moveable and fitted with the end tube and stage of the clinical microscope—a plan which has been carried out by Mr. Highley.

25. **Object-glasses required.**—The *quarter of an inch*, magnifying about 200 diameters, and *the inch*, magnifying from 30 to 50 diameters, are the two most useful object-glasses for the purposes of the medical practitioner. The best English objective costs about £5, but good powers may be obtained for about 30*s.*

26. **Microscope Lamp.**—An ordinary French lamp affords a very excellent artificial light, especially if provided with a blue glass chimney. The best form of gas lamp has been arranged by Mr. Highley, of 70, Dean Street, Soho Square. This lamp is figured in Plate IV., Fig. 20.

27. **Glass Slides**—the only slides used—should be three inches long by one inch broad. They may be purchased, at from 2*s.* to 6*s.* per gross, of Messrs. Claudet and Houghton, 89, High Holborn, E.C., and of most instrument makers.

28. **Thin Glass**, cut into squares and circles. This may be obtained of the various instrument makers, and of Messrs. Claudet and Houghton.

29. **Watch Glasses**, of various sizes. Watch glasses are very convenient for evaporating small quantities of fluids. The common glasses are those which are required. They cost 1*s.* per dozen.

30. Glass Cells, for examining urinary deposits. A simple form of cell is represented in Plate V., Fig. 25, but I have found the so-called "animalcule cages" most convenient instruments for the examination of urinary deposits. The best form is represented in Plate V., Fig. 24, which is supplied by Messrs. Powell and Lealand. Fig. 26 is a section of a smaller one, which can be used with the clinical microscope.

31. Brass Forceps, supplied by the microscope makers.

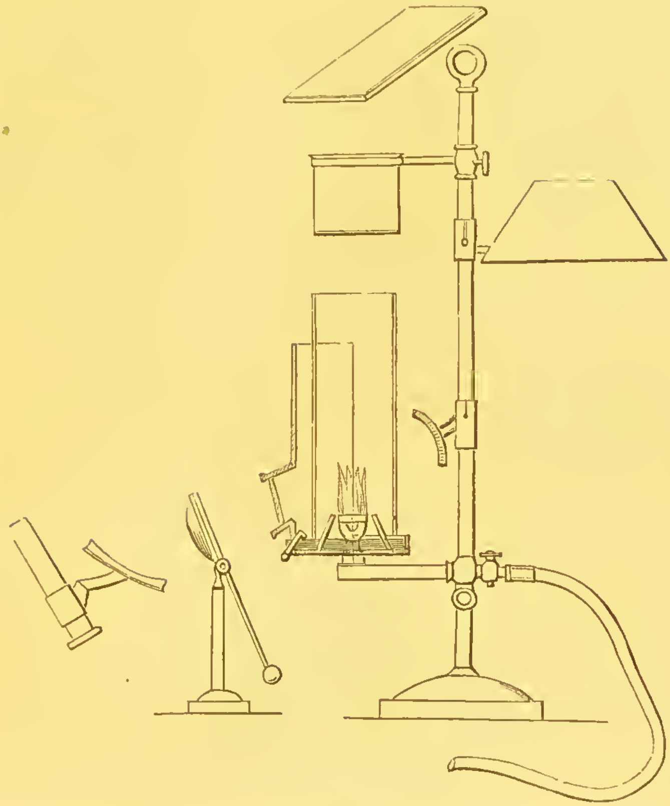
32. Stage Micrometer, divided into 100ths and 1,000ths of an inch. This is required for measuring objects, according to the plan described in "*The Microscope in Medicine*," pp. 41—45. A scale, divided to 1,000ths of an inch, and magnified 215 diameters, is represented in Plate V., Fig. 23.

33. Neutral-tint Glass Reflector, for tracing the outline of objects (Plate V., Fig. 22). It is very important that the observer should be familiar with the methods of drawing and measuring objects accurately. The arrangement of the microscope for tracing the outline of objects, with the aid of the neutral-tint glass reflector, is represented in Plate IV., Fig. 21; see also, "*The Microscope in Medicine*," p. 33.

34. Bottles with Capillary Orifices.—These bottles are most convenient for testing minute quantities. Different forms are represented in Plate V., Figs. 28, 30. They may be obtained separately, in boxes containing 6 or 12 (Fig. 27); or fitted up in a box, with other apparatus required for testing urinary deposits and calculi (Plate II., Fig. 11).

These bottles are filled as follows:—A little distilled water is poured into a small porcelain basin, the tube being inverted so that the orifice dips beneath the surface of the water. Heat being now applied to the bottle, by means of a spirit-lamp, the air in the interior is expanded, and partially expelled. As the bottle becomes cool, a certain quantity of the fluid rises up into its interior. A few drops having been introduced in this manner, the bottle is held in the test-tube holder over the spirit-lamp; and, when the water boils, and the greater part has been converted into steam, the orifice is quickly plunged a short distance beneath the surface of the liquid

Fig. 20.



§ 26.

Fig. 21.

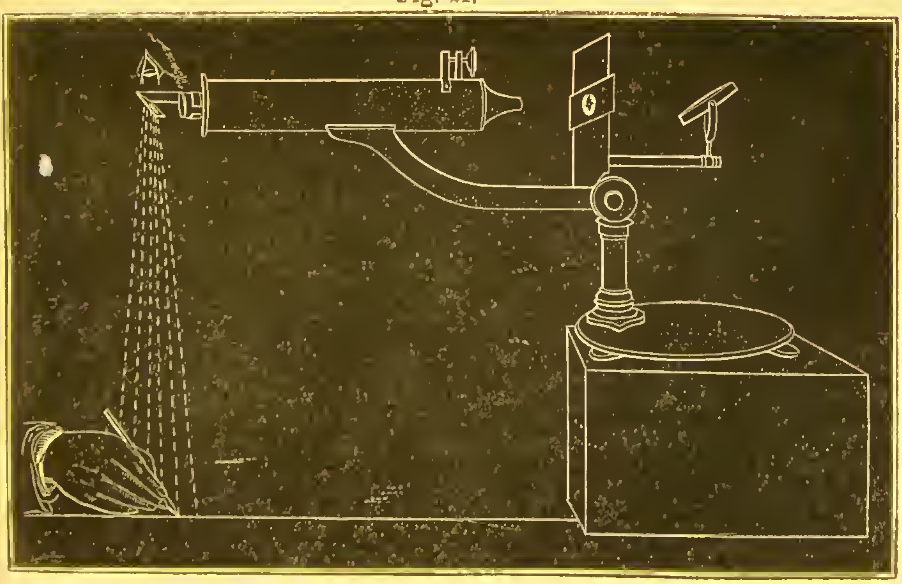


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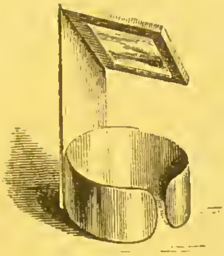
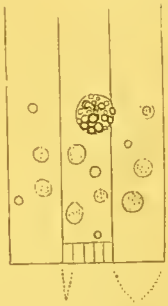
Fig. 22.



§ 33.

Fig. 23.



§ 32.

Fig. 24.

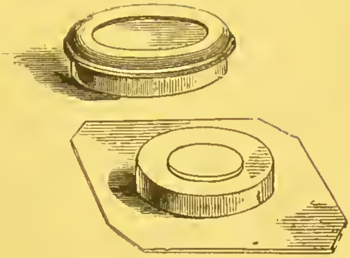


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Fig. 25.

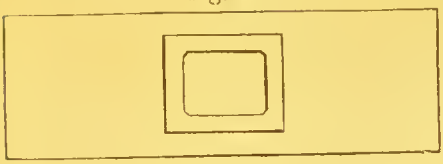

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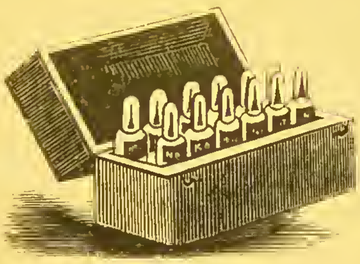
Fig. 26.

§§ 30, 58.

Fig. 27.



§ 34.

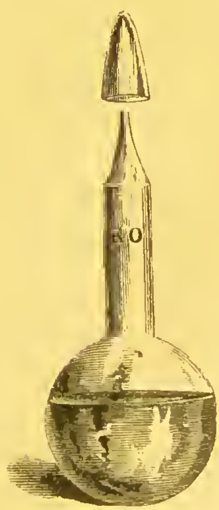
Fig. 28.

§ 34.

Fig. 29.

§ 34.

Fig. 30.



§ 34.

To follow Plate IV.

to be introduced, which has been already placed in another small porcelain capsule. As the steam condenses, the solution will, of course, rise up, and would completely fill the little bottle, if it were maintained in this position, but, when about three parts full, it is to be removed. If completely filled, it would be difficult to expel a drop, when required. A certain quantity of air, therefore, is allowed to remain within the bottle; this being expanded by the warmth of the hand, the quantity of fluid required is forced out. For microscopical purposes, these little bottles possess many advantages over the ordinary stoppered bottles. In the first place, a most minute quantity of the test can be obtained, and this can be carefully regulated. Secondly, there is no danger of the reagent being spoilt by the introduction of various foreign substances from without. If an ordinary stoppered bottle be used, a drop of fluid is generally removed with a pipette, or stirring-rod; but if these should not be quite clean, foreign substances may be introduced, and the reagent spoilt for further operations. Carelessness upon this head will lead to the greatest inconvenience, and may be productive of the most serious mistakes. Thirdly, testing by means of these little bottles can be conducted in a very short space of time; and all the tests required, even for a very complete qualitative examination, can be packed in a very small compass.

A useful form of pipette, which can be adapted to ordinary bottles, in the form of a stopper, is represented in Plate V., Fig. 34. The tube is very narrow near the end (*c*), so that a very small drop can be obtained. A piece of India-rubber is stretched over the other extremity, and by slightly pressing this a drop is expelled. This plan is recommended by Dr. Lawrence Smith, of Louisiana.

All the necessary apparatus required for the ordinary qualitative examination of urine, with tests, in bottles with capillary orifices, and apparatus necessary for the microscopical examination of urine, have been arranged in a little case, as represented in Plate II., Fig. 11. This can be purchased of Mr. Highley.

⁂ The microscopical apparatus required for the examination of urinary deposits may be obtained of Mr. Baker, Holborn; Mr. Highley, 70, Dean Street, W.; Mr. Matthews, Portugal Street, Lincoln's Inn; or it will be procured for the practitioner by the instrument makers.

CHAPTER II.

The Volumetric Process of Analysis for estimating some of the Constituents of Urine. Apparatus required. *Burettes—Pipettes—Cylindrical Glass Measure—Beakers and other Apparatus—Weights and Measures—On the Estimation of Urea and Chlorides; Determination of the Urea; Preparation of the Solution; Performance of the Analysis—Determination of the Chloride of Sodium; Preparation of the Solution; Performance of the Analysis—Estimation of Phosphoric Acid; Preparation of the Solution; Performance of the Analysis—Determination of the Sulphuric Acid; Preparation of the Solution; Performance of the Analysis—Determination of the Sugar; Performance of the Analysis—Dr. Davy's Method of Determining Urea.*

Although the general processes adopted for the estimation of the various constituents might be systematically arranged under their respective heads, it has been thought more convenient to treat of the subject of volumetric analysis in one chapter.

The ordinary methods for determining the proportion of the most important constituents in the urine possess many defects. Chemists have long found that the results are inaccurate, and not to be depended upon at all, unless great care has been taken in the process of analysis; while, at the same time, they are very laborious, and require an amount of chemical skill which few possess, unless they have been in the habit of working for some time in a laboratory. Practitioners have for years past recognised the importance, in many cases, of being acquainted with the amount of the urinary constituents removed from the body in twenty-four hours, and have desired to know how these proportions are affected by certain physiological conditions of the system, or by the administration of

remedies, or by disease. Till within the last few years, the greatest practical difficulties existed with reference to carrying out such researches. The physician was not chemist enough to undertake them; and the pure chemist, not having sufficient knowledge of medicine to enable him to see the use of such inquiries, was not interested in the matter. In practice, it will, I think, be found that all such investigations, if they are to be of any real use, must be carried on by a physician who at the same time is acquainted with chemistry. Within the last few years, the process of volumetric analysis has been introduced, principally by Professor Liebig, to whom we are entirely indebted for the excellent and accurate plan of estimating the urea and chloride of sodium. Physicians may now, with very little practice, carry on these researches; and when a sufficient number of observations have been made in various cases of disease, very important facts will, no doubt, be elicited. These processes are not free from error; but they are sufficiently accurate for all the requirements of the physician who desires to know the relative variation of the principal substances in different cases, rather than to determine the exact quantity present in a given specimen of urine. The volumetric process is, at least, as accurate as the old plans; and if it be carefully carried out, with attention to certain points of detail, much more so. In cases in which very accurate results are required, I must refer the reader to Neubauer and Vogel's treatise on the urine, where rules for all the corrections are given; but, for all ordinary purposes, the plan recommended below has been found in practice sufficiently exact. The directions here given were obtained after performing the different processes several times, and were arranged by my friend and former assistant, Dr. Von Bose, whose original paper on the subject was published in the "*Archives of Medicine*," Vol. I.

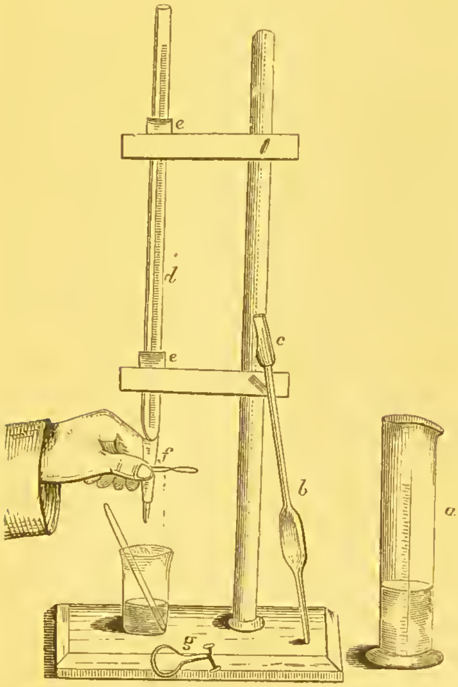
The principle of volumetric analysis is based upon the fact, that substances combine in definite and equivalent proportions. If, therefore, we accurately measure the proportion of the test required to combine with the whole of the substance present in a solution, a simple calculation, according to the chemical equivalents of the two bodies, will enable us to obtain the desired result. For instance, suppose the quantity of sulphuric acid (SO^3) in a solution is to be determined. We know that to precipitate 40 parts of sulphuric acid, exactly 122 parts of crystallised chloride of barium ($Ba\,Cl + 2\,HO$) are required,—or for 1

part of sulphuric acid, 3·05 parts of chloride of barium,—or for ·01 gramme = ·154 grain of sulphuric acid, ·0305 gr. = ·747 gr. of chloride of barium. Now, if we dissolve 30·5 gr. = 471·04 grs. of chloride of barium, in 1,000 cubic centimeters of water = 15,444 grs., or about $1\frac{3}{4}$ pint, every cub. cent. contains ·0305 gr. = ·47 grs. of chloride of barium; and if we place this solution in a tube, graduated to *cubic centimeters* or *grains*, and allow it to flow gradually into a solution of sulphuric acid as long as we get a precipitate, the number of cub. cents. used indicates the quantity of *chloride of barium* employed; and from these data we at once ascertain the proportion of *sulphuric acid* contained in the solution.

Apparatus required for Volumetric Analysis.

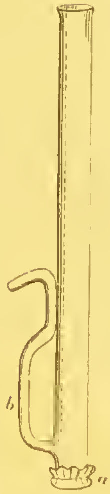
35. **Burettes or Graduated Tubes** (Plate VI., Fig. 31*d*). — It is convenient to be provided with one or more holding 50 cub. cents., and graduated to half cub. cents. The lower part of the tube is drawn to a small calibre; and to its extremity a small piece of glass tube, about two inches long, is connected by a piece of India-rubber tube, *f*, so arranged that it can be compressed at pleasure by a wire-spring, just below *f*, as represented in the figure. When the two extremities of this spring are pressed by the finger and thumb, fluid will flow down the tube; and when the pressure is removed, the tube is rendered impervious. This little apparatus serves the part of a stop-cock, and possesses many advantages over the latter. Care must be taken to keep the tube perfectly clean, and the India-rubber should be well washed after every analysis. The apparatus required for the volumetric method of analysis is represented in Plate VI., Figs. 31, 32. *a*, is a glass jar, capable of holding 500 C.C., graduated to 5 C.C. *b*, a pipette, graduated to hold 20 C.C. *c*, a piece of India-rubber tube for the convenience of allowing the fluid to escape very slowly when pressure is applied by the finger and thumb. *d*, is the burette, which is capable of holding 50 C.C., and graduated to half C.C. The numbers are not marked on the tubes in the figure. *e*, *e*, are small pieces of wide India-rubber tube to hold the burette in its place. *f*, a small piece of India-rubber tube connecting the extremity of the burette with the spout, and capable of being compressed by the spring, the form of which is represented at *g*. The mode of using the apparatus is also seen in this figure.

Fig. 31.



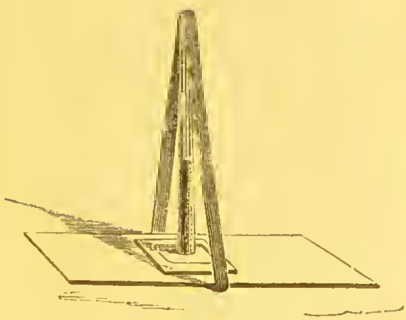
§ 35.

Fig. 32.



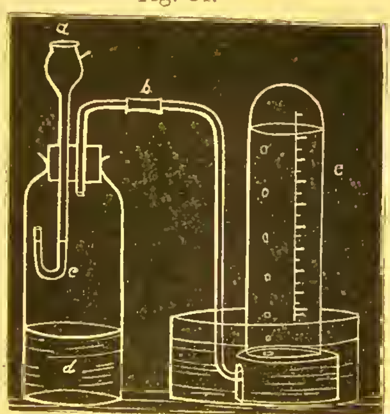
§ 35.

Fig. 33.



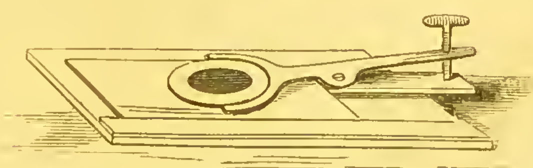
§ 55.

Fig. 34.



§ 50.

Fig. 35.



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The pipette is figured at *b*, Fig. 31. It is convenient to be furnished with one of 20 C.C. = 308·88 grs. capacity, one of 15 C.C. = 231·66 grs., and one of 10 C.C. = 154·44 grs. The *Cylindrical Glass Measure*, graduated to 500 C.C., is represented at *a*.

The little apparatus represented in Plate VI., Fig. 32, was constructed by me, for the purpose of filtering a little of the fluid from the deposit, in order to see if all the substance was precipitated. Filtering-paper is tied round the lower extremity, *a*. By plunging this beneath the fluid, the solution rises quite clear in the interior, and may be poured through the spout, *b*, into a small test-tube kept for the purpose. The drawing represents the tube half the real size. In estimating the quantity of sugar, this little apparatus will be found very convenient.

Beakers, stirring-rods, test-paper, funnels, and porcelain basins, with a tripod or small retort-stand, with a spirit-lamp or gas-lamp and small sand-bath, are also required.*

The test-solution is poured into the burette at the top till it is nearly full. A beaker is then placed beneath the orifice, and a certain quantity of fluid allowed to flow from the tube until the upper surface reaches zero on the scale. The line on the burette should always correspond to the lowest part of the thick line at the top of the fluid, caused by the capillary attraction of the walls of the tube. Care must be taken that the part of the tube below the India-rubber joint is also quite full of fluid.

It is desirable that the pipettes should be provided at their upper extremity with a short piece of India-rubber tube, *c*, Fig. 31, as, by properly-applied pressure upon this with the finger and thumb the fluid may be allowed to escape very gradually.

36. Weights and Measures.—In these directions, *weights* are expressed in grammes and grains, and *measures* in cubic centimeters and grains, so that the observer may adopt either as a standard of comparison. Tubes graduated to grains can easily be obtained, if required. The grammes, gr., and cubic centimeters, C.C., being always placed before the grains, grs. Thus, ·01 gr. = ·154 grs. is to be dissolved in 10 C.C. = 154 grs. of water.

* The apparatus referred to may be obtained of Messrs. Bullock and Reynolds, Hanover Street, Hanover Square, who also supply the test-solutions ready graduated; and of Messrs. Griffin, Bunhill Row, E.C.

37. **Estimation of Urea and Chlorides.**—The determination of urea and chlorides is effected by solutions of pernitrate of mercury ($HgO.NO^5$). The principle upon which the method depends is this, that *chlorine* gives a soluble, and *urea* an insoluble, compound with peroxide of mercury (HgO), while chlorine has a greater affinity for mercury than urea has; therefore, if pernitrate of mercury ($Hg.O.NO^5$) be added to a solution containing chlorine and urea, the chlorine will first combine with the mercury, and no precipitate of urea and mercury will take place until all the chlorine has been saturated; and if we observe how much of the solution has been used before a precipitate takes place, we can learn at once the quantity of chloride present. The volume of the solution required for completing the precipitation shows the proportion of urea, as will be explained presently. The same solution, however, is not used for both these determinations, as, for convenience in reckoning, it is better they should be of different strength. In both cases, it is necessary in the first instance to remove the phosphates from the urine. In order to effect this, a mixture of 1 volume of a cold saturated solution of nitrate of baryta ($BaO.NO^5$) and 2 volumes of saturated baryta-water ($BaO.HO$) must be prepared. This is the *Baryta-solution.*

Determination of Urea ($C^2H^4N^2O^2$).

38. **Preparation of the Solution.**—If pure mercury is procured, 71·48 gr.=1103·93 grs. are dissolved in pure nitric acid with the aid of the heat of a sand-bath. When fumes of nitrous acid (NO^3) cease to be evolved, and a drop of the solution gives no precipitate with chloride of sodium ($NaCl$), it may be evaporated on a water-bath in the beaker in which it has been prepared, to the consistence of a syrup. It is to be diluted to make a volume of 1,000 C.C.= 15444·00 grs. or about 1¾ pints; a few drops of nitric acid (NO^5) being added as often as the solution becomes turbid. In this way it will be made clear again.

If the mercury of commerce is used, a somewhat larger quantity of it is treated with nitric acid as before, but the process is stopped before it is completely dissolved: it is allowed to cool, when crystals of protonitrate of mercury ($Hg_2O.NO^5$) will form. The crystals are thrown on a filter and washed with a little nitric acid. They are to

be boiled with nitric acid, till no more vapours of n. rous acid are given off, and no precipitate is produced if a little is dropped into a solution of chloride of sodium. By evaporating a solution to the consistence of a syrup, pure pernitrate of mercury ($Hg.O.NO^5$) is obtained. This is diluted, but less water added than the solution will probably require. The proportion of mercury it contains is estimated either by sulphuretted hydrogen or by potash; and lastly, it is diluted so as to contain ·772 gr. = 11·92 grs. of peroxide of mercury (HgO) in 10 C.C. = 154·44 grs.

1 C.C. = 15·44 grs. of this solution, made according to either of the above methods, indicates 0·01 gr. = 0·154 gr. of urea.

39. Performance of the Analysis.—In the first place, 40 C.C. = 617·76 grs. of the urine are mixed with 20 C.C. = 308·88 grs. of the baryta solution: the precipitate is filtered, and 15 C.C. = 231.66 grs. of the filtrate are placed in a small beaker. These 15 C.C. contain 10 C.C. of urine. The burette is next filled with the solution, which is added as long as the precipitate is observed to increase. The following test is then applied, to ascertain if a sufficient quantity has been added. A drop of the mixture is removed with a glass rod and placed on a watch-glass. A drop of a solution of carbonate of soda ($Na.O.CO^2$) is then placed near the first, and the two drops are allowed to flow together. If they give a white precipitate, the process is not yet finished; more of the mercury solution must be added, and a drop tested as before, till the two drops, when they coalesce, give a yellow precipitate, which shows an excess of mercury. A second experiment may be made to confirm the first; and lastly, by reading off the number of the C.C. used, the quantity of urea contained in the urine is immediately ascertained. Still there is a correction to be made: the first drops of the solution which produced no precipitate did not combine with, and do not, therefore, correspond to, any of the urea present. This volume must be deducted, or about two cubic centimeters may always be subtracted from the volume of the test-solution used.

Determination of Chloride of Sodium (Na.Cl).

40. Preparation of the Solution.—17·06 gr. = 263·47 grs. of pure mercury are dissolved as before described, and the syrup diluted to a volume of 1,000 C.C. = 15444·00 grs.. or about 1¾ pints, as in the

last case. Or, the solution of pernitrate of mercury ($HgO.NO^5$), made from the impure mercury, which has been analysed, is diluted in such proportion, that 10 C.C. of it may contain ·184 gr. = 2·84 grs. of peroxide of mercury (HgO).

1 C.C. of this solution answers to ·01 gr. = ·154 gr. of chloride of sodium.

41. **Performance of the Analysis.**—·40 C.C. = 617·76 grs. of urine are mixed, as before, with 20 C.C. = 308·88 grs. of the baryta solution; 15 C.C. = 231·66 grs. of the filtered mixture are placed in a beaker and rendered acid by a few drops of nitric acid. The burette is filled with the test-solution, which is allowed to drop into the beaker, the mixture being continually stirred with a glass rod. As soon as the precipitate at first formed does not disappear by stirring, the operation is finished, and the volume of the solution used is read off. This shows the quantity of chloride of sodium contained in the urine.

With regard to removing the phosphates, in both cases it is to be remarked that, if 1 part of the baryta solution to 2 parts of the urine should not precipitate the whole (a point easily ascertained by adding some of the baryta solution to a few drops of the filtered mixture), more of the baryta solution must be added. This then would somewhat modify the quantity of the mixture to be taken for the test. Suppose it is desired that it should still contain 10 C.C. = 154·44 grs. of urine in it. 17½ C.C. = 270·27 grs. of the mixture would be required, if there were 3 parts of baryta solution to 4 parts of urine; 20 C.C. = 308·88 grs. would be taken if there were equal parts of baryta solution and urine. More than this will hardly ever be required.

Estimation of Phosphoric Acid.

The estimation of the phosphoric acid by this process is not so exact as those last described, and the greatest care must be taken. A solution of perchloride of iron is added, after the fluid to be tested has first been mixed with a solution of acetate of soda and free acetic acid.

If perchloride of iron be added to a solution containing phosphoric acid, a precipitate of phosphate of iron is produced; at the same time hydrochloric acid, which would redissolve the phosphate, is set free from the perchloride. In order to prevent this, acetate of

soda is added in the first instance; the free hydrochloric acid decomposes the acetate of soda, and acetic acid is set free, in which the phosphate of iron is insoluble.

42. Preparation of the Solutions.—1. *Solution of Perchloride of Iron*—15·556 gr. = 240·24 grs. of pure iron wire are dissolved in pure hydrochloric acid, to which a little nitric acid has been added. The solution is evaporated to dryness on a water-bath, and the residue dissolved in water and diluted to 1,000 C.C. = 15,444 grs. Or a solution of perchloride of iron of moderate strength is prepared. The iron is estimated as peroxide by adding ammonia, and the solution is diluted so as to contain 1·556 gr. = 24·024 grs. of iron in 100 C.C. = 1544·4 grs. In preparing this solution, care must be taken to avoid an excess of hydrochloric acid. One C.C. of this solution indicates ·01 gr. = ·154 grs. of phosphoric acid.

2. *Solution of Acetate of Soda and Acetic Acid.* 20 gr. = 308·88 grs. of crystallised acetate of soda, are dissolved in 100 C.C. = 1544·4 gr. of water, and mixed with 100 C.C. = 1544·4 grs. of acetic acid.

3. *Solution of Ferrocyanide of Potassium.* 1 gr. = 15·44 grs. of ferrocyanide of potassium are dissolved in 100 C.C. = 1544·4 grs. of water.

43. Performance of the Analysis.—100 C.C. = 1544·4 grs. of the urine, are mixed with 10 C.C. = 154·44 grs. of the solution of acetate of soda. The whole is divided into five parts—*a*, *b*, *c*, *d*, *e*—with a pipette, each part containing 20 C.C. = 308·88 grs. of urine. The burette is filled with the iron solution, and into each of the parts half a C.C. more of the solution is dropped, beginning with six half C.C., so that

a, *b*, *c*, *d*, *e*, contain
6 7 8 9 10 half C.C.

of the iron solution. They are left for 5—10 minutes, then 3 C.C. = 46·3 grs. of each are filtered into five test-tubes kept ready; and to the filtrates 1 C.C. = 15·4 grs. of the solution of ferrocyanide of potassium is added. If in any of them the deep blue colour of Prussian blue appears, the analysis is finished, and the results may be confirmed by a second experiment. If the colour does not appear, five half C.C. more must be added to each of the parts, so that

a, *b*, *c*, *d*, *e*, now contain
11 12 13 14 15 half C.C.;

and, after standing again, the same test is applied. This process must be repeated until the deep blue colour is obtained. The confirmatory analysis is better made by taking 50 C.C. = 772·2 grs. of urine in each of five beakers, mixing the fluid in each of them with 5 C.C. = 77·22 grs. of the acetate solution, and adding the proportional numbers of half C.C., that are near those indicated by the first experiment. If, for instance, the colour appeared at 12 half C.C., there must be added 28, 29, 30, 31, 32 half C.C., to the different portions of the urine.

44. **Estimation of the Earthy Phosphates** (*Phosphate of Lime and Magnesia*).—The quantity of phosphoric acid combined with earths (earthy phosphates) may be determined as follows:—First, in one portion of the urine the whole amount of phosphoric acid is estimated as above; in another portion, the earthy phosphates are precipitated by a little ammonia, and the phosphoric acid in combination with alkalies in the filtered fluid is volumetrically determined. The difference between both analyses indicates the quantity of phosphoric acid combined with the earths.

If the urine to be tested is alkaline, and contains a deposit of earthy phosphates, the latter must first be dissolved in as little hydrochloric acid as will take it up.

It is important to familiarise the eye with the tint of colour obtained; and care should be taken always to obtain the same tint.

Determination of the Sulphuric Acid.

45. **Preparation of the Solution.**—A quantity of crystallised chloride of barium is to be powdered, and dried between folds of blotting-paper. Of this, 30·5 gr. = 471·04 grs. are to be dissolved in 1,000 C.C. = 15444·00 of distilled water.

A dilute solution of *sulphate of soda* is also required.

46. **Performance of the Analysis.**—100 C.C. = 1544·4 grs. of the urine are poured into a beaker, a little hydrochloric acid added, and the whole placed on a small sand-bath, to which heat is applied. When the solution boils, the chloride of barium test is allowed to flow in very gradually as long as the precipitate is seen distinctly to

increase. The heat is removed, and the vessel allowed to stand still, so that the precipitate may subside. Another drop or two is then added, and so on, until the whole of the SO^3 is precipitated. Much time, however, is saved by using the little apparatus represented in Fig. 32. A little of the fluid is thus filtered clear, poured into a test-tube, and tested with a drop from the burette; this is afterwards returned to the beaker, and more of the test solution added, if necessary. The operation is repeated until the precipitation is complete. In order to be sure that too much of the baryta-solution has not been added, a drop of the clear fluid is added to the solution of sulphate of soda placed in a test-tube. If no precipitate occurs, more *chloride of barium* must be added; if a slight cloudiness takes place, the analysis is finished; but, if much precipitate is produced, too large a quantity of the test has been used, and the analysis must be repeated.

For instance, suppose 27 half-cubic centimeters = 208·47 grs. have been added, and there is still a slight cloudiness produced, which no longer appears after the addition of another half-cubic centimeter = 7·722 grs. of the solution, we know that between 27 and 28 half-cubic centimeters are required to precipitate the whole of the sulphuric acid present, and 100 C.C. = 1544·4 of urine contain between ·135 and ·14 gr. = 2·085 and 2·162 grs. of *sulphuric acid.*

Determination of the Sugar.

This method is deduced from the reaction occurring when Trommer's test is employed for testing for grape-sugar. It is well known that grape or diabetic sugar possesses the power of reducing the oxide of copper to the state of yellowish-red sub-oxide.

47. Preparation of the Solution.—An alkaline solution of sulphate of copper is prepared with the aid of *tartaric acid* and *potash.* The former prevents the precipitation of the oxide of copper by the potash. 40 gr. = 617·76 grs. of crystallised sulphate of copper, are dissolved in about 160 C.C. = 2471·04 of water. Next, 160 gr. = 2471·04 grs. of neutral tartrate of potash, are to be dissolved in a little water, and from 600 to 700 gr., about 9,500 *grs.* of a solution of soda of 1·12 specific gravity, are to be mixed with it. The solution of the sulphate of copper is added gradually, and the whole

diluted with water to a volume of 1154·4 C.C. = 17828·5 *grs.*; 10 C.C. = 154·4 *grs.* of this solution correspond to ·05 gr. = ·772 *grs.* of sugar.

48. **Performance of the Analysis.**—10 C.C. = 154·4 grs. of the copper solution are diluted with 40 C.C. = 617·7 grs. of water, and placed in a porcelain dish. About 20 C.C. = 308·8 *grs.* of the urine are diluted with from ten to twenty times their bulk of water, so as to produce, for instance, 300 C.C. = 4633·2 grs. This is to be poured into the burette, and adjusted so as to fill it to the 0° of the scale. The dish with the copper solution is arranged on a sand-bath placed on a tripod stand, at a convenient distance beneath the orifice of the burette. A spirit or gas-lamp is applied until the copper solution approaches the boiling-point, when the urine is allowed to flow in gradually. The mixture is then boiled for an instant, and left for half an hour or more, when the suboxide will have subsided to the lower part. If, after the deposit has settled, the solution possesses a blue tinge, which is easily detected against the white porcelain, the analysis is not finished. More urine is to be added, and the mixture again boiled. This operation is to be repeated as long as any unreduced oxide remains in solution. The process is finished when the supernatant fluid is colourless. The little filtering apparatus described in § 35, and figured in Plate VI., Fig. 32, may be used as soon as the solution is boiled; and, if the whole of the copper has not been precipitated, the clear solution exhibits a blue tint. This saves time in performing the analysis. The proportion of sugar present in the urine is easily calculated.

Suppose 24 C.C. = 370·6 *grs.* of the diluted urine have been required to reduce the 10 C.C. = 154·4 *grs.* of the copper solution, these 24 C.C. contain ·05 gr. = ·772 *grs.* of sugar. But since 300 C.C. of the dilute solution contain only 20 C.C. = 308·8 grs. of the urine, the 24 C.C. contain only 1·6 C.C. = 24·7 *grs.* Therefore, 1·6 C.C. = 24·7 *grs.* of urine contain ·05 gr. = 0·772 *grs.* of sugar, or in 100 C.C. = 1,544 grs. of urine, 3·12 gr. = 48·18 *grs.* of sugar are present.

*** The volumetric process of analysis of the urinary constituents is described at greater length in Neubauer and Vogel's "*Analyse des Harns*," now being translated for the Sydenham Society; and in Dr. Thudichum's "*Treatise on the Pathology of the Urine.*"

49. Davy's Mode of determining Urea.—A long stout glass tube, 12 or 14 inches in length, capable of holding two and a half cubic inches, is closed at one end, and ground perfectly smooth at the open extremity, and graduated to tenths and hundreds of a cubic inch. It is to be filled more than a third full of mercury, and afterwards a measured quantity (from a quarter of a drachm to a drachm) of the urine poured in. Next, the tube is exactly filled with a solution of chlorinated soda (hypochlorite of soda, sodæ chlorinatæ liquor, of the Dublin "*Pharmacopœia*"). Care must be taken to avoid adding too much of the solution, which must be poured in quickly. The orifice of the tube is instantly covered with the thumb; inverted once or twice, to mix the urine and hypochlorite; and placed beneath a saturated solution of salt and water contained in a cup. The mercury flows out, and the solution of salt takes its place; but, being more dense than the mixture of urine and hypochlorite, the latter always remains in the upper part of the tube. The urine is soon decomposed, bubbles of nitrogen escape, and collect in the upper part of the tube. When decomposition is complete, which is known by no more bubbles of gas being evolved, the volume collected is read off, and corrected for temperature and pressure.

One-fifth of a grain of urea should furnish by calculation ·3098 parts of a cubic inch of nitrogen at 60° F. and 30′ Bar. In one experiment, Dr. Davy obtained from the same quantity ·3001; in another, ·3069.

Amount of Urea in an Ounce of Urine, as estimated by Dr. Davy, according to Liebig's Method and his own.

		Liebig's.	Dr. Davy's.
First experiment	..	3·680	3·712
Second experiment	..	5·328	5·472
Third experiment	..	4·976	4·976

("*Dublin Hospital Gazette*," 1855, vol. i., p. 134; Braithwaite's "*Retrospect*," 1854, vol. xxx., p. 109.)

50. Modification of Davy's Method.—Dr. Handfield Jones has found that the results obtained by this plan were not so trustworthy as could be wished, and suggests the following modification. ("*Archives of Medicine*," vol. i., p. 144.)

'Lately I have used a bottle, of about six ounces capacity,

with a curved tube of supply, and another to conduct away the gas into a graduated jar (Fig. 34, Plate VI.). *a* is the supply tube; *b*, the out-leading tube; *c*, fluid remaining in curve of supply tube; *d*, mixture in bottle; *e*, receiver to hold and measure the gas generated. After the urine is poured in, the supply tube is washed out with a little water. Of course, at any time, more solution of chlorinated soda (measured quantity) can be added through the supply-tube. I put into the bottle two drachms of urine or more, adjust the out-leading tube to the jar, and pour in, with a pipette, a known bulk of solution of chloride of soda.* This drives over, of course, a corresponding amount of air, and the gas generated, a further amount, so that in the jar I have an amount which – the volume of decomposing fluid = the gas generated. I have ascertained by trial that no alteration of volume takes place when air and nitrogen are mixed. The fluid remaining in the curved supply-tube bars all escape of gas, and it is perfectly easy to empty the bottle afterwards by simply inverting it, when the contents pour out of the gas escape-tube. By shaking the bottle frequently, I can get an experiment finished in about an hour."

"In six trials (some of them being made with a straight tube of supply, going to the bottom of the jar, instead of a curved one), I obtained the following results:—

			Observed.			Calculated.	
(*a*) 2	grains of urea	gave	3·305 C. in.	instead	of	3·098 C. in.	or ·207 +
(*b*) 2	"	"	3·0979	"	"	3·098	or ·0001 –
(*c*) 1·5	"	"	2·3107	"	"	2·323	or ·0123 –
(*d*) 1·3	"	"	2·1313	"	"	2·0137	or ·1276 +
(*e*) 2·5	"	"	3·8498	"	"	3·8725	or ·0227 –
(*f*) 2	"	"	3·0256	"	"	3·098	or ·0724 –

"These are not exact enough to satisfy me, but I do not see any source of fallacy in the mode; and, if in more skilful hands it should prove trustworthy, I think it would have much to recommend it, on the score of facility in previous preparation. The figures have been corrected for temperature and pressure."

* "The solution of chloride of soda used by Dr. Davy is the sol. sod. chlor. of the Dublin '*Pharmacopœia*.' I find that it is not every specimen that serves the purpose well; what I have used lately has been made for me by Mr. Button, Holborn Bars. A fresh solution (filtered) of chloride of lime acts very energetically and quickly, much more so than the sol. sod. chlor., but some carbonic acid is generated and passes over, which complicates the process."

51. Results of Liebig's and Davy's Methods compared.—In some comparative experiments on Liebig's and Davy's methods, Dr. Handfield Jones obtained the following results :—

Urine specific gravity 1,024, full coloured—
By Liebig, gave 15·920 grains of urea per ℥ i.
By Davy, „ 16·640 „ „

Urine specific gravity 1,007, pale, clear—
By Liebig, ℥ i gave 5·250 grains.
By Davy, ℥ i „ 2·636 „

Urine specific gravity 1,029, paleish, lateritious—
By Liebig, ℥ i gave 16·125 grains.
By Davy, ℥ i „ 17·224 „

Urine specific gravity 1,018, albumen, separated—
By Liebig, ℥ i gave 10·500 grains.
By Davy, ℥ i „ 9·760 „

Dr. Von Bose has also estimated the proportion of urea in the same specimen of urine, by the two methods. Ten cubic centimeters of six different specimens of urine gave the following results :—

	Liebig's Method.	Davy's original Method.
1	·365 gr.	·310 gr.
2	·335 „	·260 „
3	·370 „	·295 „
4	·225 „	·269 „
5	·247 „	·231 „
6	·220 „	·253 „

*** The apparatus required for the volumetric analysis of urine may obtained of Messrs. Griffin, Bunhill Row, E.C.; Messrs. Bullock and Reynolds, 3, Hanover Street, W. ; and at most operative chemists and philosophical instrument makers. The graduated tubes may also be obtained of Messrs. Negretti and Co., Holborn Hill.

CHAPTER III.

Examination and Preservation of Urinary Deposits. *Collecting Urine for Microscopical Examination—Period when the Urine should be examined—Removal of the Deposit from the Vessel containing it—of Collecting a very small quantity of a Deposit from a Fluid—Magnifying Powers required in the Examination of Urine—of the Chemical Examination of Urinary Deposits—Examination of the Deposit in the Microscope—of placing the Deposit in the Preservative Fluid—Refractive Power of the Medium in which Deposits are mounted—Media in which Urinary Deposits may be preserved—of keeping the Deposit for subsequent Inquiries—of preserving Deposits permanently—Mucus, Epithelium, Fungi, and Vegetable Growths—Spermatozoa—Casts—Pus—Phosphates, Urates, Blood Corpuscles, Uric Acid, Cystine, Oxalate of Lime—on preserving Crystalline Substances which are more or less soluble in Water.* Of Extraneous Matters of Accidental Presence—*Larvæ of the Blow-fly—Hair—Cotton and Flax Fibres—Portions of Feathers—Silk—Fibres of Deal from the Floor—Starch Granules—Portions of Tea Leaves—Milk—Sputum—Epithelium from the Mouth—Vomit.*

Examination of Urinary Deposits.

The examination of urinary deposits is now a subject of such great importance, and the advantages derived from it are so generally admitted, that I need scarcely refer to its value, in assisting us to form a diagnosis in many cases of disease. Within the last fifteen or twenty years, the investigation of urinary deposits has been much simplified, and the results obtained by the conjoint use of the microscope and chemical analysis have been so accurate and decided, that the nature of the greater number of deposits has been definitely determined.

When the student commences to examine urinary deposits for the first time, he will doubtless meet with many difficulties; and in some specimens which he examines, he will perhaps discover no deposit whatever; whilst in examining others, the whole field of the microscope is seen to be occupied by substances of various shapes and colours, the nature of which he will be unable to ascertain. Many of the substances which lead to this difficulty have obtained entrance into the urine accidentally; and the observer should therefore be warned against mistakes easily made, which are serious, and may bring great discredit upon his powers of observation. Portions of hair have been mistaken for casts of the renal tubes; starch-granules for cells; vegetable hairs for nerve fibres; casts for the basement membrane of the uriniferous tubes; and many other substances of extraneous origin, such as small portions of woody fibre, pieces of feathers, wool, cotton, etc., often take the form of some of the urinary deposits, and to a certain extent resemble the drawings given of them in their general appearance, so as to mislead the student in his inferences, and retard his progress in investigation.

52. **Collecting Urine for Microscopical Examination.**—Urine, which is to be submitted to examination, should be collected in considerable quantity, in order to obtain sufficient of the *deposit* for examination. In many instances, the amount of sediment, even from a pint of urine, is so small that, without great care in collecting, it may be altogether passed over. The amount of deposit from a measured quantity of urine should always be roughly noted. The space occupied by the deposit may be compared with the total bulk of the fluid, and we may say the deposit occupies a fifth, a fourth, half the bulk of the urine, etc.

Bottles used for carrying specimens of urine should be made of white glass, with tolerably wide mouths, and capable of holding at least four ounces; but if the sediment only of the urine is required, the clear supernatant fluid may be poured off, after the urine has been allowed to stand for several hours, and the remaining deposit may then be poured into small bottles of an ounce capacity, or even less. The only objection to this latter mode of collecting urine is, that no estimate of the *amount* of sediment deposited by a given quantity of urine can be formed. The bottles may be arranged in a case capable of containing two, four, or six. They may be obtained

of Messrs. Weiss, in the Strand; Mr. Highley, 70, Dean Street, W.; Mr. Matthews, near King's College Hospital; and other instrument makers.

53. **Period when the Urine should be Examined.**—In all cases the urine should, if possible, be examined within a few hours after its secretion; and, in many instances, it is important to institute a second examination after it has been allowed to stand for twenty-four hours or longer. Some specimens of urine pass into decomposition within a very short time after they have escaped from the bladder; or the urine may even be drawn from the bladder actually decomposed. Under these circumstances, we should expect to find the secretion highly alkaline, having a strongly ammoniacal odour, and containing crystals of triple phosphate, with granules of earthy phosphate; and upon carefully focussing, numerous vibriones may generally be observed. In other instances, the urine does not appear to undergo decomposition for a considerable period, and may be found clear, and without any deposit, even for weeks after it has been passed.

In those cases in which *uric acid* or *octohedral crystals of oxalate of lime* are present, the deposit increases in quantity after the urine has stood for some time. These salts are frequently not to be discovered in urine immediately after it is passed, but make their appearance in the course of a few hours. The deposition of uric acid depends upon a kind of acid fermentation, which has been the subject of some beautiful investigations by Scherer (§ 119).

In order to obtain sufficient of the deposit from a specimen of urine for microscopical examination, we must place a certain quantity of the fluid in a conical glass (§ 12); in which it must be permitted to remain for a sufficient time to allow the deposit to subside into the lower part.

54. **Removal of the Deposit from the Vessel containing it.**—In order to remove the deposit from the lower part of the vessel in which it has subsided, the upper end of the *pipette* is to be firmly closed with the forefinger, the tube being held by the thumb and middle finger. Next, the lower extremity is to be plunged down to the bottom of the deposit. The forefinger may now be raised very slightly, but not completely removed, and a few drops of the fluid with the deposit slowly pass up into the tube (Fig. 9, Plate II.).

When a sufficient quantity for examination has entered, the forefinger is again pressed firmly upon the upper opening, and the pipette carefully removed. A certain quantity of the deposit is now allowed to flow from the pipette on to the glass slide or cell, by gently raising the forefinger from the top. It is then covered with the thin glass cover, and subjected to examination in the usual way. Dr. Venables recommends that the deposit should be obtained by inverting a corked tube into which the urine has been previously poured. A small quantity of the deposit adheres to the cork, and may be removed to a glass slide; but, as a general rule, the plan above described will be found efficient.

55. Of Collecting a very small quantity of a Deposit from a Fluid.—When the quantity of deposit is very small, the following plan will be found of practical utility. After allowing the lower part of the fluid which has been standing, to flow into the pipette, as above described, and removing it in the usual manner, the finger is applied to the opening, in order to prevent the escape of fluid when the upper orifice is opened by the removal of the finger. The upper opening is then carefully closed with a piece of cork. Upon now removing the finger from the lower orifice, the fluid will not run out. A glass slide is placed under the pipette, which is allowed to rest upon it for a short time. It may be suspended with a piece of string, or supported by the little retort stand. Any traces of deposit will subside to the lower part of the fluid, and must of necessity be collected in a small drop upon the glass slide, which may be removed and examined in the usual way.

Another plan is to place the fluid, with the deposit removed by the pipette, in a narrow tube, closed at one end, the bore of which is rather less than a quarter of an inch in diameter. This may be inverted on a glass slide, and kept in this position with a broad elastic India-rubber band. The deposit, with a drop or two of fluid, will fall upon the slide, but the escape of a further quantity of fluid is prevented by the nature of the arrangement, which will be understood by reference to Plate VI., Fig. 33.

56. Magnifying Powers required in the Examination of the Urine.—Urinary deposits require to be examined with different magnifying powers. The objectives most frequently used are the inch and the quarter of an inch. The former magnifies about 40

diameters (× 40); the latter from 200 to 220 (× 200, × 220). Large crystals of uric acid may be readily distinguished by the former, but crystals of this substance are sometimes so minute that it is absolutely necessary to use high powers. Octohedra of oxalate of lime are frequently so small that they cannot be seen with any power lower than a quarter; and, in order to bring out the form of the crystals, even higher object-glasses than this are sometimes necessary. Spermatozoa may be seen with a quarter, but they then appear very minute. In these cases, an eighth of an inch object-glass, which magnifies about 400 diameters (× 400), will be of advantage. The casts of the tubes, epithelium, and the great majority of urinary deposits, can, however, be very satisfactorily demonstrated with a quarter of an inch object-glass.

A deposit, the nature of which is doubtful, should be subjected to examination in fluids possessing different refractive powers, such as water, serum, mucilage, glycerine, turpentine, Canada balsam, etc.

57. **Of the Chemical Examination of Urinary Deposits.**—In the investigation of those deposits which are prone to assume very various and widely different forms, such as uric acid, it will often be necessary to apply some simple chemical tests, before the nature of the substance under examination can be positively ascertained.

Suppose for instance, a deposit which is found, upon microscopical examination, not to possess any characteristic form, be suspected to consist of uric acid, or of an alkaline urate, it is only necessary to add a drop of solution of potash, which would dissolve it, and then excess of acetic acid, to obtain the crystals of uric acid in their well-known rhomboidal form. Other chemical tests which should be considered necessary may be applied afterwards.

When it is requisite to resort to chemical reagents, a drop of the test-solution is to be added to the deposit, which is placed in the cell, or upon the glass slide. The little bottles described in § 34 will be found most convenient for this purpose. If necessary, heat may be applied to the slip of glass by a spirit-lamp, and, with a little practice, the student will soon be able to perform a qualitative analysis of a few drops of urine, or of a very small portion of a deposit.

58. **Examination of the Deposit in the Microscope.**—The drop of urine with the deposit is to be placed in a thin glass cell, or

in one of the animalcule cages (§ 30, Plate V., Figs. 24, 26). These instruments will be found convenient for examining urinary deposits, as a stratum of fluid of any degree of thickness can be very readily obtained. A simple form of compressorium may be also conveniently used for the examination of urinary deposits (Plate VI., Fig. 35).

Various parts of the specimen are to be brought into the field of the microscope. It is better to examine the object as regularly as possible, commencing on one side, and moving it up and down, until the whole has been traversed. After one specimen has been examined, and the nature of its contents noted, another may be treated in a similar manner. Specimens should be taken from the deposit at different levels, for while some deposits soon sink to the bottom, others are buoyed up, as it were, either by the small quantity of mucus which the urine contains, as is the case with small crystals of oxalate of lime, or by the flocculent nature of the deposit itself.

As each part of the deposit is brought under the field of the microscope, the observer should endeavour to recognise every object as it passes under his view. This, however, will for some time be found a matter of considerable difficulty, arising partly from the number of deposits which commonly occur together, and partly from the very various forms which many of these substances are liable to assume, but chiefly, I believe, from the great number of substances of accidental presence which are found in almost every specimen of urine subjected to examination; especially in urine obtained from the wards of a hospital, upon which the first microscopical observations are usually made. Accurate copies of the different urinary deposits, drawn on the stone with the aid of the glass reflector (§ 33), are represented in the plates of the "*Illustrations of Urine, Urinary Deposits, and Calculi.*"

I cannot too strongly recommend the observer to sketch the appearances of the different deposits which come under his notice. He will by so doing become familiar with the characters of urinary deposits much more quickly than if he merely instituted a hasty and imperfect examination. The methods of obtaining sketches of the exact size of the image in the microscope, are described in "*How to Work with the Microscope.*" (See also § 33.)

62.—Refractive Power of the Medium in which Deposits are Mounted.—The appearance of objects in the microscope depends very much upon the medium in which they are immersed; and many structures are so altered in their character by different media, that they would hardly be recognised as the same object. It may be said, generally, that the darker the object, and the more dense its structure, the higher should be the refractive power of the medium in which it is mounted—thus the dark-coloured uric acid, or the thick spherical crystals of carbonate of lime, and the dumb-bells of oxalate of lime, exhibit their structure to the greatest advantage when mounted in the highly refracting *Canada balsam*, or in *strong syrup* or *glycerine*, while the beautifully transparent octohedra of oxalate of lime would be scarcely visible in these media, and require to be mounted in an aqueous fluid which possesses a lower degree of refractive power. Many of these objects, when mounted dry, appear quite dark, and scarcely exhibit any structure at all, in consequence of the great difference in the refracting power of their substance, and the air by which they are surrounded. From what has been said, it will be evident how important it is to examine the same object in different media—in fact, it is quite impossible to form an idea of the real structure of many specimens, without proceeding in this manner. ("*How to Work with the Microscope*," p. 59; and "*The Microscope in its Application to Practical Medicine*," second edition, §§ 74, 89, and 90.)

63.—Media in which Urinary Deposits may be Preserved.—Urinary deposits may be mounted in *air*, in *turpentine*, *oil*, or *Canada balsam;* in *glycerine*, in *gelatine and glycerine*, in *solution of naphtha and creasote*, in *certain saline solutions*, in *weak spirit*, and in some other aqueous solutions, which will be alluded to. The *glycerine* which I use is "*Price's patent glycerine*," diluted with one third part, or more, of water. In making more dilute solutions of glycerine, it is well to employ camphor water, as this prevents the formation of fungi. Many urinary deposits may be preserved in strong glycerine, if care be taken to increase the density of the solution gradually, and sufficient time be allowed for the deposit to be thoroughly permeated with the fluid. The best plan is to add a little glycerine to the deposit which has been allowed to collect in the conical glass. After the deposit has settled, pour off the

supernatant fluid and add fresh glycerine. Repeat the same process two or three times. I have kept specimens preserved in strong glycerine for ten years with very slight change; and probably they will retain their character for a much longer time than this.

The composition of the naphtha and creasote fluid, above referred to, is as follows:—

Solution of Naphtha and Creasote.

Creasote	3 drachms.
Wood naphtha........................	6 ounces.
Distilled water	64 ounces.
Chalk, as much as may be necessary.	

Mix first the naphtha and creasote, then add as much prepared chalk as may be sufficient to form a smooth thick paste; afterwards add, very gradually, a small quantity of the water, which must be well mixed with the other ingredients in a mortar. Add two or three small lumps of camphor, and allow the mixture to stand in a lightly covered vessel for a fortnight or three weeks, with occasional stirring. The almost clear supernatant fluid may then be poured off and filtered, if necessary. It should be kept in well corked or stoppered bottles.

64. Of keeping the Urinary Deposit for subsequent Inquiries.—In cases where it is desirable to retain a certain quantity of the deposit in the preservative solution for subsequent examination, or for the purpose of making more preparations, it should be kept in a small glass tube, with a tight-fitting cork, and carefully labelled. Most urinary deposits may be kept for a longer time in this manner than if mounted in thin cells. I propose now to describe briefly the various plans adapted for the preservation of urinary deposits which I have found to succeed best.

Preservation of Special Deposits.

65. Mucus.—It is very difficult to preserve the character of the so-called "mucus corpuscles," or imperfectly formed epithelial cells, nuclei, and granules, which constitute the slight flocculent deposit met with in healthy urine, and termed "mucus." The naphtha and creasote solution is best adapted for the purpose, and it is desirable to place the specimen in a cell about the twentieth of an inch in depth.

66. **Epithelium.**—The different varieties of epithelium are easily preserved, although, after the lapse of some time, minute oil globules make their appearance in them. They may be kept in naphtha and creasote fluid, to which one-fourth of its bulk of glycerine has been added. It is well to put up specimens of epithelium from the urethra, bladder, ureter, and pelvis of the kidney, removed from the organs of a healthy man who has been killed accidentally. They should be mounted in very thin cells. Specimens of the epithelium from the vagina, which can generally be obtained from the urine of females, should also be preserved.

67. **Vegetable Growths: Fungi.**—I have found that fungi may be preserved most satisfactorily in glycerine, for although they appear somewhat more transparent in this fluid than in urine, they preserve their general character better than when immersed in other preservative fluids. It is necessary to add weak glycerine in the first instance, and to increase the strength gradually, otherwise the fungi become collapsed, owing to the great density of the strong solution. A solution composed of equal parts of water and Price's glycerine is sufficiently strong to preserve fungi. I have not been able to preserve specimens of sarcinæ which I have met with on two or three occasions in the urine, probably in consequence of their extreme delicacy. The sarcinæ which are from time to time met with in vomit keep perfectly well, and preserve their recent characters in glycerine.

68. **Spermatozoa** are sometimes mounted in the dry way; but although their general form is preserved, their refractive power and transparent appearance are so different from what is observed when they are immersed in urine, that little is gained from such preparations. Spermatozoa keep very well in glycerine, although they appear rather more faint than in an aqueous fluid. They should be examined with the *eighth of an inch object-glass* (× about 400); but when the eye of the observer has become familiar with the general appearances, they may be readily recognised with a quarter of an inch object-glass (× about 200).

69. **Casts.**—It is not difficult to preserve the character of some varieties of casts. The transparent casts often become covered with numerous minute granules and oil globules, and their character much altered. Granular casts and epithelial casts often keep very well in

the naphtha and creasote solution; but altogether I prefer glycerine, with one-third part of water. Although, in many instances, the cells they eontain are altered, and oil globules appear much more transparent than when in urine, this alteration in character may be easily allowed for. The specimens in glycerine, of coursc, keep admirably. I have some speeimens of large waxy easts and epithelial easts whieh have been kept in the naphtha and creasote solution for upwards of sevcn years, and still prcserve their charactcrs well. Some casts may also be preserved in gelatine and glycerine, care being takcn that the mixture is not madc too hot. Casts may be coloured slightly with an ammoniaeal solution of carmine, and preservcd in glyeerine. The very transparcnt casts, which are hardly visible under ordinary circumstances, ean thus be demonstrated vcry clearly and prcserved. Any nuelci in the cast are intensely eolourcd by the carmine.

70. **Pus.**—Recent speeimens of pus may be so readily obtaincd that it is hardly necessary to attempt to preserve the eorpuseles permanently. Their characters alter so much in all the aqueous preservative fluids that I have tried, that after they have been put up for some time, it would be difficult to reeognise the nature of the prcparation. I have, however, succeeded in preserving some specimens of pus in glycerine by observing the precautions mentioned in § 63. Cancer eells, whieh are somctimes found in very large quantities in the urine in eases of cancer of thc bladder, may be preserved in the same manner. I have several speeimens which have been mounted for five or six years.

71. **Phosphates.**—The phosphate of lime, in its amorphous form, in globulcs, and minute dumb-bclls, is easily preserved in weak spirit, naphtha and ereasote fluid, or glycerinc; but the charaeter of the crystals of the triple or ammoniaco-magnesian phosphate could not be rctaincd in this solution. As is well known, this salt is quite insoluble in solutions of ammoniacal salts, and these make the best preservative solutions for it. Crystals of triple phosphate may be kept for any length of timc, with their smooth surfaces and their lustre unimpaired, in distilled water, to which a little ehloride of ammonium has bccn added. Phosphate of limc and the stellar form of triple phosphate may bc dried carefully, and mounted in Canada balsam; but, of eourse, the appearanee of the crystals is a good deal altcred.

72. **Urates.**—As the urates are so commonly met with, and as they are generally deposited in the form of granules, there is scarcely any need of mounting them as permanent objects. If desired, however, deposits of this kind may be preserved by adding a little naphtha and creasote fluid to the deposit, which should be left in it for a considerable time before it is put up. Urates which crystallize in small spherical masses, as often occur in the urine of children, and more rarely in irregular branched processes, may be preserved very well in Canada balsam, or, if preferred, they may be kept in the naphtha and creasote fluid.

73. **Blood Corpuscles** become more or less altered in most preservative fluids. I think that those which I have mounted in glycerine (one part water to three parts of glycerine) have undergone the least change.

74. **Uric Acid Crystals** are easily preserved as permanent objects. The usual plan is to mount them in Canada balsam. They should be washed, in the first instance, with a little water, to which a few drops of acetic acid have been added. When pretty clean, they may be placed upon a glass slide, with the aid of a pipette, and the greater quantity of the fluid absorbed with a small piece of bibulous paper. After the crystals have been properly arranged on the slide with a needle, they may be dried, by exposure under a bell jar over a dish containing sulphuric acid. When quite dry, they may be moistened with a drop of turpentine, and mounted in Canada balsam. In this operation, a very slight heat should be employed, otherwise the crystals will become cracked in all directions, and more or less opaque. Uric acid crystals, as a general rule, do not keep well in glycerine. In cases where we wish to preserve other substances in the deposit as well as uric acid crystals, the naphtha and creasote fluid will be found to answer very well. I have some preparations mounted in this manner, which were put up six or seven years ago.

75. **Cystine.**—Crystals of cystine may be preserved in Canada balsam, the same care being taken in mounting them as mentioned under uric acid, or they may be kept very well in distilled water, or in the naphtha and creasote fluid, to which a little acetic acid has been added.

76. Oxalate of Lime.—Both the octohedra and dumb-bells may be preserved for many years in the naphtha and creasote solution and also in glycerine. The octohedra look very transparent in the latter fluid. The dumb-bells may also be mounted in Canada balsam, in which medium the octohedra are almost invisible. When required for polarising, these and other crystals should be put up in balsam.

77. On Preserving Crystalline Compounds obtained from Urine.—It is exceedingly difficult to preserve many of the crystalline substances obtained from urine in a moist state; but several of them form beautiful microscopic objects when carefully dried. *Urea, nitrate of urea, oxalate of urea, creatine, creatinine, alloxan, hippuric acid, murexid*, and many others, may be kept as permanent objects in this manner. In order to prepare them, it is better to cause them to crystallize upon a glass slide; allow the mother liquor to drain off, and immediately place the slide under a bell-jar over sulphuric acid. Sometimes the crystals may be made in a small evaporating basin, and when drained and dried, a portion of them may be removed to a glass cell, and covered with a piece of thin glass to exclude the dust. Many crystals may be examined and preserved for a considerable time in their own mother liquor, especially when they are very slightly soluble in fluid; but, as a general rule, this plan does not answer very satisfactorily, for, independently of the escape of the fluid from the edges of the cell, a few of the largest crystals grow still larger at the expense of the smaller ones, and the beauty of the specimen is destroyed. The different forms of these crystals, as they appear in the microscope, are given in the "*Illustrations of Urine, Urinary Deposits, and Calculi*," "*Urine*," Plates I. to IX.; *see* also "*The Microscope in its Application to Practical Medicine*," chap. ix., p. 292.

Of Extraneous Matters.

78. Importance of recognising Extraneous Matters.—In the microscopical examination of urinary deposits, the observer often meets with substances the nature and origin of which he cannot readily determine. This is due, in many instances, to the presence of bodies which have fallen in accidentally, or which have been placed in the urine for the express purpose of deceiving the practitioner. The importance of recognising matters of an extraneous

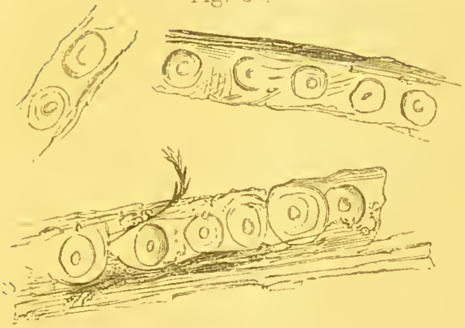
origin can scarcely be sufficiently dwelt upon, for until the eye becomes familiar with the characters of these substances, it will obviously be quite impossible to derive such information from a microscopical examination of the urine as will enable the observer to distinguish between those bodies, whose presence denotes the existence of certain morbid conditions, and certain matters which have accidentally found access, which, clinically speaking, may be entirely disregarded. Practitioners who use the microscope for investigating the nature of urinary deposits, will derive advantage from subjecting many of the substances referred to separately to microscopical examination, so that when met with in the urine, their nature may be at once recognised. As most of the undermentioned substances are readily obtained and easily subjected to examination, a brief notice of their character will be sufficient. Attention should be especially directed to the fact of the frequent occurrence of many of these extraneous substances in urine, and the observer should particularly notice those characters in which they resemble any insoluble substance derived from the bladder or kidney, or deposited from the urine.

The following are some of the most important of these extraneous matters which have fallen under my own notice :—

Human hair.
Cat's hair.
Blanket hair.
Worsted.
Wool.
Cotton and flax fibres.
Splinters of wood.
Portions of feathers.
Fibres of silk.
Milk.
Oily matter.
Potato starch.
Wheat starch.
Rice starch.
Tea leaves.
Bread crumbs.
Chalk.
Sand.

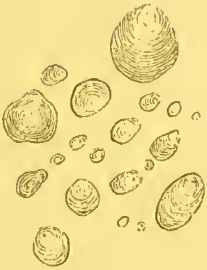
The microscopical appearances of some of these substances are given in Plate VIII., Figs. 36, 37, and 38, *see* also Plates I., II., and III., Figs. 1 to 16, of the "*Illustrations of Urine, Urinary Deposits and Calculi.*" It would hardly be believed what curious and unexpected substances are sometimes found in the urinary secretion. Some time since, a specimen of urine was sent for examination, which contained several white bodies, about half-an-inch in length, like maggots. Upon microscopical examination, I found that these con-

Fig. 36.



§ 84. × 215.

Fig. 37.



§ 85. × 215.

Fig. 38.

§§ 80, 81, 82, 85, 86, 87 × 215.

To face page 38.

tained tracheæ, and they ultimately proved to be *larvæ of the blowfly*, although it had been stoutly affirmed that they had been passed by the patient from his bladder.

79. **Sesquioxide of Iron.**—A few years ago, Dr. Stewart informed me that a man had brought some urine to him for examination, with a thick, brick-red deposit, which was analysed by Mr. Taylor, and proved to consist of sesquioxide of iron. The urine containing this deposit, was of specific gravity 1·011; and upon the addition of ammonia, a brown flocculent precipitate (hydrated sesquioxide of iron) was thrown down. Dr. Stewart tells me, that a considerable quantity of the powder (jeweller's rouge, or sesquioxide of iron) remained suspended in the urine after it had stood for many hours, and that the fluid was still turbid after having been passed through a double filter. The man who brought this urine has been endeavouring for some time to impose upon different hospital physicians.

80. **Hair** of various kinds is very frequently found amongst urinary deposits, but, as its microscopical appearance is so well known, it is not necessary to enter into a description of the characters by which it may be distinguished. The varieties of hair most commonly found are human hair, blanket hair, and cat's hair. Not unfrequently portions of coloured worsted will be met with; but the colour alone will often remove any doubts with reference to the nature of the substance. Portions of human hair are sometimes liable to be mistaken for transparent casts of the uriniferous tubes, which are quite destitute of epithelium or granular matter, and which present throughout a homogeneous appearance. The central canal, with the medullary cells within it, in many cases, will be sufficient to distinguish the hair from every other substance likely to be mistaken for it (Plate VII., Fig. 38*a*); but sometimes this cannot be clearly made out, and the marks on the surface may be indistinct; when attention must be directed to its refracting power, well defined smooth outline, and also to the sharply truncated or fibrous ends, or to its dilated club-shaped extremity in the case of the hair-bulb. In the latter points, small portions of hair will be found to differ from the cast, for this latter does not refract so strongly; the lines on each side are delicate, but well defined, and the ends are seldom broken so abruptly as in the case of the hair. Cat's hair (Fig. 38*b*) can scarcely be mistaken for any urinary deposit with which I am acquainted,

and its transverse markings will serve at once to distinguish it with certainty. (*"Illustrations,"* Plate I., Figs. 1, 2, 3.)

81. **Cotton and Flax Fibres** are very often found in urine (Fig. 38 *d*, *e*). When broken off in very short pieces, they may be mistaken for casts; but the flattened bands of the former (*e*), and the somewhat striated fibres of the latter (*d*), will generally be found sufficiently characteristic. (*"Illustrations,"* Plate III., Fig. 16; Plate I., Fig. 4.)

82. **Portions of Feathers** are often detected in urinary deposits upon microscopical examination, and are derived, no doubt, from the bed or pillow (Fig. 38*g*). The branched character of the fragments will always enable the observer to recognise them with certainty. (*"Illustrations,"* Plate III., Fig. 14.)

83. **Pieces of Silk** are not unfrequently present, but these can scarcely be mistaken for any substance derived from the kidney. Their smooth glistening appearance and small diameter, at once distinguish them from small portions of urinary casts, and their clear outline and regular size from shreds of mucus, &c.

84. **Fibres of Deal from the Floor.**—Of all the extraneous matters likely to be met with in urine most calculated to deceive the eye of the observer, none are more puzzling than the short pieces of single fibres of deal (Plate VII., Fig. 36). In hospitals, where the floor is uncovered, and frequently swept, portions of the fibres of the wood are detached, and being light, very readily find their way into any vessel which may be near. In fact, these fibres enter largely into the composition of the dust which is swept up. I was familiar with the appearance of these bodies for a long time before I ascertained their nature; for, although the peculiar character of coniferous wood is sufficiently well marked, when only very small portions are present, and in a situation in which they would scarcely be expected to be met with, their nature may not be so easily made out. Often only two or three pores may be seen, and not unfrequently these are less regular than usual, in which case they may be easily mistaken for a small portion of a cast with two or three cells of epithelium contained within it. I have very frequently met with these fibres amongst the deposit of various specimens of urine which have been

obtained from private as well as from hospital patients. ("*Illustrations*," Plate III., Fig. 15.)

85. **Starch Granules** are very commonly found in urinary deposits, and indeed in all matters subjected to microscopical examination; usually their presence is accidental, but large quantities of starch have often been added for purposes of deception. Their true nature may be discovered, either by their becoming converted into a jelly-like mass on being boiled with a little water in a test-tube, by their behaviour upon the addition of free iodine, or by their well-defined microscopical characters. Certain cases have been recorded, in which it was maintained that the starch granules present in the urine had passed from the kidney; but it need scarcely be said that such an origin is very improbable, if not quite impossible. In cases where due care has been taken to prevent the access of starch globules after the urine had been passed, none were observed. We learn by experience that we can seldom receive the statements of patients upon these matters, however positive they may be. They often deceive themselves as to the actual occurrence, in their own case, of what never has occurred and never can occur. The three kinds of starch most likely to be met with in urine are potato starch (Plate VII., Fig. 37), wheat starch (Fig. 38*h*), and rice starch. They are readily distinguished by microscopical examination. Small portions of potato, or pieces of the cellular network in which the starch globules are contained, have been occasionally met with. Under the head of starch may also be included bread-crumbs (Fig. 38*h*), which are very commonly present in urine, and have a very peculiar appearance, which may be so easily observed, that a description would appear superfluous. Many of the starch-globules will be found cracked in places, but their general characters are not otherwise much altered. ("*Illustrations*," Plate II., Figs. 6, 7, 8, 9, 10, 11.)

86. **Portions of Tea-leaves** are occasionally found in urine (Fig. 38*f*). The beautiful structure of the cellular portions, and the presence of minute spiral vessels, distinguish this from every other deposit of extraneous origin. A small piece of a macerated tea-leaf will be found to form a most beautiful microscopic object. ("*Illustrations*," Plate I., Fig. 5.)

87. Milk and certain Colouring Matters are sometimes purposely added to urine; and it is often difficult to make out whether they have been added with the intention of deceiving us, especially as urine is sometimes met with, having all the appearance of milk (chylous urine); and certain colouring matters, such as logwood and indigo, when taken into the stomach may be absorbed by the vessels, and eliminated from the system in the urine. A form of Indigo, there can be no doubt, is actually produced in the urine.

Urine, to which milk has been added, can be distinguished from the so-called chylous or milky urine by its microscopical characters. The presence of small oil-globules, with a well defined dark outline, can always be detected in milk by the aid of the microscope, while in chylous urine nothing but a great number of very minute and scarcely visible granules, composed of fatty matter, can be made out. ("*Illustrations*," Plate III., Fig. 13.) I have had several specimens of milky urine sent to me for examination, upon the supposition that they were examples of chylous urine, and in some the milk had been added in sufficient quantity to yield a firm curd, after standing for a day or two, and a precipitate upon the addition of acetic acid. Where only a very small quantity of milk is added, the difficulty of deciding positively is greatly increased. The globules are, I believe, characteristic. Some cases of chylous urine are recorded, in which the fatty matter existed in distinct globules; and therefore we cannot unfortunately lay it down, that in *all* cases of this disease, the fatty matter is in a *molecular state*. In the six or seven true cases of chylous urine, which have been brought under my own notice, the fatty matter was in this very minute state of division; and in several supposed ones, in which *oil-globules* were present, they were proved to have resulted from the addition of milk for the purpose of deception, or from the use of an oiled catheter. The observer should also be familiar with the appearance of oil-globules under the microscope (Fig. 12).

88. Sputum: Epithelium from the Mouth: Vomit. It must be remembered, too, that epithelium from the mouth is often found in urine. All the cells met with in sputum are occasionally found, and a vast number of different substances, which are rejected by vomiting, are from time to time detected. The observer must not be surprised at finding now and then some well defined elementary fibres

of striped muscle. It is most difficult to prevent these different substances from being mixed with the urine. They often cause the microscopist great trouble—and especially at first, before the eye has become quite familiar with their appearance, they are likely to give rise to the greatest confusion in descriptions of microscopical appearances. For the microscopical characters of the substances present in sputum and vomit, I must refer to "*The Microscope in its application to Practical Medicine*," and the Plates in the third part of "*Illustrations of the use of the Microscope in Clinical Medicine*."

CHAPTER IV.

The Anatomy of the Kidney—Its Action in Health and Disease—*Cortical and Medullary Portions of the Kidney —Pelvis—Mamillæ—Infundibula and Calyces—Artery— Vein—Nerves—Lymphatics—Secreting Apparatus—The Uriniferous Tube—Of the Circulation in the Kidney— Epithelium—Of the Basement Membrane of the Tubes and of the so-called Matrix—On some Points connected with the Physiology of the Kidney—On the formation of Casts of the Uriniferous Tubes—Of the Cast—Circumstances under which the Renal Secretion may be altered in Quantity or Quality—On the Absorption of Substances from the Stomach, and their excretion in the Urine—Morbid Changes affecting the Structure of the Kidney—Of Bright's Disease—Dr. Johnson's Investigations.*

It is clearly impossible to discuss with advantage the characters of the urine in health and disease, or the formation of urinary calculi, without studying the anatomy and action of the kidney. As these organs are essentially concerned in the removal from the organism of soluble substances resulting from disintegration, the accumulation of which in the blood would most seriously impair the action of many important organs, they are worthy of special study on the part of every physician. It is not too much to say that, without a good knowledge of the anatomy and physiology of the kidney, it is impossible for the practitioner to understand the nature of a very large and important class of diseases, and it is certain that cases of one or other form of renal disease will very frequently come under the notice of all engaged in practice in large cities. Nor are kidney diseases exclusively confined to the inhabitants of cities. Moreover, there are no diseases in which the

practitioner can be of more real service to the patient, and none which it is more important to recognise at once. The treatment of many of these morbid conditions has been satisfactorily determined, and there is no department of medicine in which the knowledge we possess is more definite and accurate, or in which the practical utility of our knowledge is more manifest. A thorough acquaintance with the physiological changes occurring in the kidney will alone enable us, to the greatest advantage of our patients, to suggest and apply remedies in various cases of disease. For these reasons, therefore, I consider it right to describe briefly the anatomy and action of the kidney before considering the characters of the urine.

I shall describe the anatomy as simply as I can, and in order to spare words I have made several drawings to illustrate the structure and arrangement of the various tissues entering into the formation of the renal apparatus. The subject is so extensive that I cannot hope to do more than offer some very brief remarks; and I shall omit discussing many points connected with the pathology which would be necessary to give my account any pretensions to completeness.

89. General Anatomy.—The general anatomy of the kidney is shown in section in the diagram (Fig. 39, Plate VIII). Each kidney is enclosed in a capsule composed of fibrous tissue, but abundantly supplied with blood-vessels, and with lymphatics. At the hilus or notch, the capsule is continuous with the areolar tissue which surrounds the large vessels, and extends in intimate relation with them for a certain distance into the interior of the organ. Fig. 39, Plate VIII. shows the general structure of the kidney as seen upon section. The *ureter* traced upwards is continuous with the pelvis of the kidney. From the *pelvis*, narrow funnel-shaped prolongations *(infundibula)* are observed. These extend to the *pyramids*, being reflected around the apex of each to form a cup-shaped depression *(calyx)*. The apices of some pyramids are also seen opening into the infundibula towards the observer. The *cortex* extending round the kidney and passing inwards between the pyramids, is easily distinguished from the *medullary portion*, by the irregular granular appearance it presents to the unaided eye, and by the numerous minute points *(Malpighian bodies)* seen in it. The medullary

portion is composed of the pyramids, which consist of tubes which are nearly straight, and converge to the apex or *mamilla*, where they open by about fifteen or twenty orifices. Portions of arteries and veins are observed between the infundibula, and smaller vessels are seen in the section between the cortex and medulla. These give branches in two directions, *outwards* to the cortex, and *inwards* to the pyramids. The drawing is about two-thirds of the natural size. The scale at the side is divided into eight spaces, representing half-inches.

90. **Cortex.**—The *cortex* or *cortical portion* of the kidney consists of a layer about half an inch in thickness, forming the surface of the entire organ, and dipping down often to the depth of an inch between the pyramids.

91. **Medullary Portion.**—This lies immediately within the cortex, and is directly continuous with its inner surface. It is composed of from ten to fifteen pyramids, their bases being continuous with the cortex; their apices free, and projecting into the cavity in the interior of the organ *(pelvis of the kidney)*.

92. **Pelvis: Mamillæ: Infundibula: Calyces.**—The mucous membrane, with the fibrous and muscular tissue externally, forms a dilated cavity in the interior, called the pelvis (*c*, Fig. 40). From the pelvis, passing towards the apices of the pyramids, are several tubular prolongations, forming funnel-shaped channels (infundibula), *e*, *d*, usually not more than twelve in number. In many cases, two pyramids open into one infundibulum. Each of these funnel-shaped prolongations forms a cup-like cavity round the tip of the pyramid (*mamilla* or *papilla*), called a *calyx*, *f*. Lastly, the mucous membrane, after forming this reduplication, is firmly adherent to the mamillæ, and immediately continuous with that lining the tubes, which open by orifices varying from ten to twenty or more in number, upon the summit (*h*, Fig. 40, Plate VIII.). Some of the free extremities of the pyramids are thin, and extend in a longitudinal direction, perhaps for the distance of a quarter of an inch or more. The term mamilla or papilla can hardly be properly applied to these.

The pelvis is dilated at the notch or hilus, where it leaves the kidney, and soon contracts to a tube with muscular parietes (ureter),

which opens into the bladder—one on each side of this viscus, at its posterior aspect. Fig. 40, Plate VIII., represents a thin section of a portion of the kidney. *a*, cortical; *b*, medullary portion; *c*, pelvis; *d*, infundibulum; *e*, opening of an infundibulum into pelvis; *f*, calyx; *g*, pyramid; *h*, mamilla or papilla; *i*, adipose tissue; *k*, large veins divided in making the section. Small arteries are also seen cut across in different parts of the section, some large branches being situated between the cortex and medullary portion of the organ.

93. **Artery.**—Outside the mucous membrane of the pelvis of the kidney, the artery, entering at the hilus behind the vein, divides into branches, which are distributed to the organ. The branches of the artery do not anastomose, but radiate outwards as they divide and pass towards the cortex. Arrived at a point between the cortical and medullary portions of the kidney, many branches pursue for some distance a more or less horizontal, or rather curved course, corresponding to the bases of the pyramids. From these, radiating outwards in the cortex, pass a number of nearly straight branches, which give off on all sides little vessels which terminate in Malpighian bodies. The great bulk of the blood carried by the artery to the kidney is distributed to Malpighian bodies; but a few small arterial branches pass straight through the cortex, and supply the capsule; others are distributed upon the external surface of the pelvis, and ramify amongst the adipose tissue in the neighbourhood; while some (*vasa recta*) are given off from the vessels that lie between the cortex and medulla, many branches of which I have shown, anastomose with each other, and pass in the substance of the pyramids towards their apices.

94. **The Emulgent or Renal Vein** is formed by the union of a number of smaller trunks which receive the blood from the capillaries. Numerous large branches may be seen in the intervals between the cortex and medulla (Fig. 40, *k*). They converge from all points, receiving the blood distributed by the artery as above described, and at length form one large trunk, which emerges at the hilus at its anterior part, and opens into the inferior cava.

95. **Nerves.**—The nerves are branches of the sympathetic, and are distributed upon the coats of the artery. They may be traced for a considerable distance into the interior of the gland, always

accompanying the subdivisions of the artery. I have seen branches on the Malpighian arteries, but have not been able to ascertain how they terminate. It is possible that small branches may pass into the Malpighian tuft. I have seen numerous very fine branches of nerve fibres passing between the uriniferous tubes of the frog's kidney. The kidney of the frog receives many branches of nerve fibres, besides those which pass into it with the artery. In the human subject all the arteries and the vasa recta are freely supplied with nerve-fibres and numerous very fine fibres, with nuclei connected with them ("connective tissue corpuscles" of authors), lie around the tubes.

96. **Lymphatics.**—There are numerous lymphatic vessels distributed to the kidney. They leave the organ at the hilus, where the large vessels enter. I have not succeeded in injecting these lymphatics as I have in the case of the liver, where they exist in great number, and are found both in the substance of the capsule and in the portal canals. The capsule of the kidney is, probably, also supplied with lymphatics, although it is not easy to demonstrate them by injection.

97. **Secreting Apparatus: Uriniferous Tubes.**—The secreting apparatus consists of tubes lined with epithelium. The tube commences in a small flask-like dilatation, which embraces the capillary vessels of the Malpighian tuft (Fig. 41, Plate VIII.). In continuation with this is the tube which, in the greater part of its extent, is very much convoluted, being frequently bent upon itself; so that a great length of secreting tube is packed in a very small space. The convoluted tubes are so close together, that it is impossible to trace, in man and mammalian animals generally, the course of one individual tube for any great distance; and, in thin sections of the cortex, segments of the windings of different tubes are seen divided in all directions.

The tubes, as they are about to leave the cortex, pursue an almost straight course, and here commences the ductal portion of the urinary apparatus. A certain number of these straight tubes extend nearly to the surface of the kidney, and carry off the secretion from the tubes which lie most superficially. These may be seen lying in the cortex, at certain intervals. In the pyramids, the tubes are straight; and as they converge, they unite together, and become fewer in number; while their calibre greatly increases as they pass towards the apex

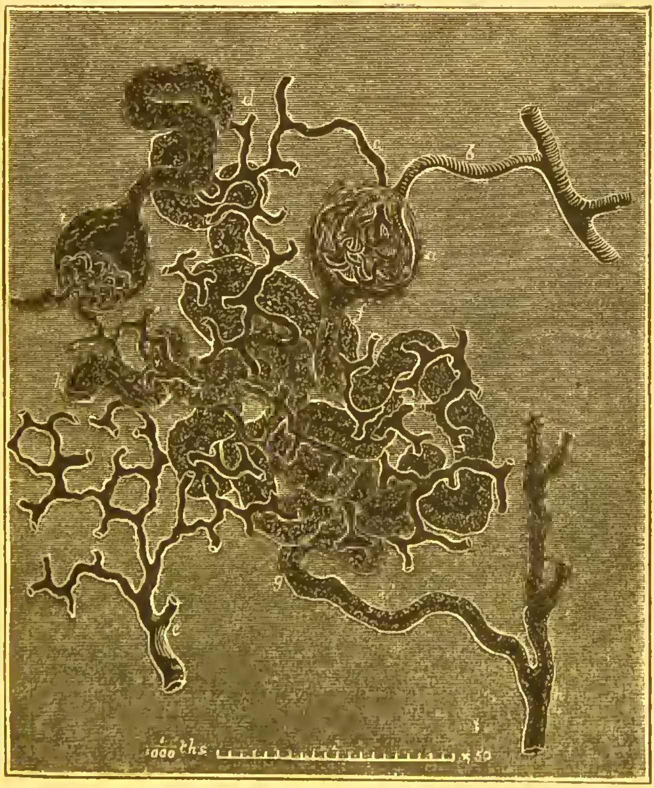
Fig. 39.

§ 89.

Fig. 40.

§ 92.

Fig. 41.



§ 97.

× about 50

To face page 48.

of the pyramid, where they open as before described. Some of these orifices are figured in Plate XXII., Fig. 5, Vol. i., "*Archives of Medicine*, 1859."

98. **Summary of Structure.**—The *cortex* of the kidney, then, is composed of Malpighian bodies, the flask-like dilatations and convoluted portion of the uriniferous tubes, with capillaries, the arrangement of which will be presently considered, branches of arteries and veins, with a certain amount of transparent and fibrous tissue.

The *medullary portion* is composed of the pyramids, which are formed of the straight portion of the uriniferous tubes with capillaries, bundles of small straight branches (vasa recta) from the arteries, and numerous straight branches of small veins; the majority of these nearly straight vessels, however, consists of vessels resulting from the division of the efferent vessels of the Malpighian bodies situated nearest the pyramids (Plate IX., Fig. 42). There is also an intervening material containing nuclei, and having a very firm consistence, but not a distinctly fibrous network or stroma.

99. **Circulation in the Kidney.**—The course of the blood, as it circulates in the vessels of the kidney, may now be described. Starting from the arterial branches between the cortex and medullary portion of the organ, the blood pursues two directions—*outwards* towards the external surface, and *inwards* towards the apices of the pyramids.

Of the blood which passes *outwards*, a little is distributed to the capsule and membrane of the pelvis, but by far the larger proportion is carried to the Malpighian bodies. Arrived at the Malpighian body, the trunk of the little artery divides into three or four dilated branches, each being as wide as the artery itself. These subdivide into capillary loops which have their convexity towards the uriniferous tube, and which lie uncovered by epithelium within its dilated commencement; so that fluids passing through the membranous walls of these capillaries, and, indeed, everything escaping from them when they are ruptured, must at once pass into the uriniferous tube. The blood is collected from the capillaries by small venous radicles which lie in the central part of the tuft, which there unite to form a single efferent vessel that emerges usually at a point very close to that by which the artery entered. In some specimens, I have seen two and even three efferent vessels, but this is not common.

The arrangement of the secreting structure and vessels of the kidney of man, magnified about 50 diameters, is represented in the drawing, Plate VIII., Fig. 41; *a*, Malpighian body; *b*, Malpighian artery or afferent vessel; *c*, efferent vessel; *d*, capillary network, into which the blood passes from the efferent vessel; *e*, small venous radicle, which carries off the blood after it has traversed the capillaries just alluded to; *f*, commencement of the uriniferous tube by a dilated extremity, which embraces the vessels of the tuft; *g*, the tube; near the point where it opens, it joins others, *h*, to pursue a straight course towards the pyramids of the kidney; *i*, another tuft, the vessels of which are empty and shrunken; *k*, portion of a tube cut across, showing the basement-membrane. The attention of the reader is particularly directed to this figure.

The *efferent* vessel of the tuft pursues a short course, and then divides into an extensive network of capillaries, in the meshes of which the tubes ramify. It is from the blood, which, after passing through one system of capillaries in the tuft, thereby losing much of its water, slowly wanders in a more concentrated state, through this extensive capillary system, that the solid constituents of the urine are separated by the agency of the epithelial cells lining the tubes. The water, *fully charged with oxygen*, transuding from the capillaries of the Malpighian body, is made to traverse in succession the epithelial cells lining the tube. At the same time that it dissolves the different substances which have been separated from the blood, it *oxidises* the matter forming the outer part of the cells, and converts it into soluble substances. The blood becomes richer and richer in solid constituents as it approaches the straight portion of the tube. From the intertubular network of capillaries above alluded to, the blood is collected by small venous radicles, which at last pour their contents into the renal or emulgent vein.

100. **Vasa recta.**—Of the comparatively small quantity of the blood which passes *inwards* towards the apex of the pyramids, a very small portion passes into vessels which supply the walls of the pelvis and adipose tissue. The remainder is conducted towards the apex of the pyramid by the *vasa recta*, or branches resulting from the division of small trunks of the *artery*, one of which is represented at *a*, Plate IX., Fig. 42. These *vasa recta* terminate in a capillary network, in the longitudinal meshes of which the straight portion

of the tubes lies. It must not be concluded, however, that all the straight vessels in the pyramids are vasa recta, with the structure of arteries; for the efferent vessels of those tufts near the pyramids divide into long and nearly straight branches, which pour their blood into this system of capillaries, from which it is collected by radicles which also pursue a straight course, and unite together to form small trunks, which open into branches of the vein lying between the cortical and medullary portions of the kidney. This arrangement was fully described by Bowman in his memoir. He thought that *all* the straight vessels came from the Malpighian bodies. Virchow seems to consider that all, or very nearly all, the straight vessels consist of vasa recta; but I have shown by *transparent injections* that many of these vessels are the efferent vessels from Malpighian bodies, as Bowman long ago stated, while a certain number undoubtedly come directly from arteries (Plate IX., Fig. 42). The latter have the structure of arteries, and are freely supplied with nerve fibres. In diseases, in which much more blood is made to pass into the pyramids than normally, the coats of these arterial branches become much thickened, and the circular fibres are more readily demonstrated than in health. ("On the Vasa Recta in the Pyramids of the Kidney," *Archives of Medicine*, No. IV., 1859.)

It should be mentioned, that the intertubular capillaries are everywhere continuous; and from this network venous radicles arise at certain intervals. The arrangement of the capillaries is well shown in the frontispiece of the "*Illustrations of Urine, Urinary Deposits, and Calculi.*"

101. Epithelium.—The epithelium of the kidney differs in different parts of the tube. That in the convoluted portion of the tube is described as being polygonal; it projects into the tube to the extent of one-third of its calibre. That in the straight portion of the tube is flatter, and approaches to the scaly variety of epithelium. Although the convoluted portion of the tube is much wider than the straight portion, *the diameter of the channel is much wider in the latter position than in the former*, owing to the much greater thickness of the epithelium in the secreting portion of the tube. Epithelium from the convoluted portion of the uriniferous tube is represented in Plate IX., Fig. 44; *a*, treated with acetic acid. × 215.

In healthy human kidneys, I have never seen the outline of the

cells so distinctly as figured in various works, or in the upper part of my own figure. The round body, usually termed the nucleus, is very clear and well defined, and this seems to be surrounded by a quantity of soft granular matter. I think it very doubtful if there is a cell wall external to this. In many cases of disease, the round central body is all that can be made out; and sometimes these are found in great number in the urine. The round 'cells' present in the urine, in cases of acute nephritis, are generally the nuclei of the 'cells' lining the uriniferous tube, the soft granular material around having been completely disintegrated. By the action of acetic acid, nucleoli may be observed. It would seem as if the granular matter external to the rounded granular body (nucleus) was altered in character under certain circumstances. From numerous observations, I feel compelled to dissent from the descriptions generally given both of the kidney and liver epithelium, inasmuch as the appearance of a cell-wall can only be seen under certain circumstances; and in many animals there is undoubtedly no such structure. I would rather say that the so-called nuclei are embedded in a granular material, by which they are separated from each other by nearly equal distances, as represented in the lower part of Fig. 44, Plate IX. If, instead of using the terms *nucleus*, *cell-wall*, and *cell contents*, we consider the central mass as germinal or living matter, which is coloured by carmine, and the outer granular matter as "formed material," the changes actually observed can be described without any difficulty or confusion. The formed material is rendered transparent by acetic acid, as represented at *a*, Fig. 42, and during life it is slowly converted into soluble substances by the action of the oxygen dissolved in the water discharged from the Malpighian capillaries.

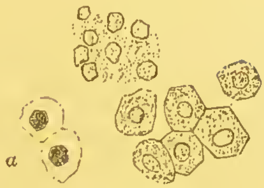
The epithelium in the straight portion of the tube is much flatter than that in the convoluted part, and probably serves the office of a protective covering. It is doubtful if it takes part in secretion. The epithelium from the pelvis of the kidney is represented in Plate IX., Fig. 45, and that from the ureter in Fig. 46.

102. **Matrix and Basement-Membrane of the Tubes.**—The basement-membrane is easily demonstrated by washing a thin section of the kidney, so as to remove the epithelium. It is much stronger and thicker in the pyramids than in the cortex (Plate IX., Fig. 43*b*).

Fig. 42.

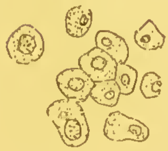
§ § 98, 100

Fig. 44.



§ 101 × 215

Fig. 45.



§ 101

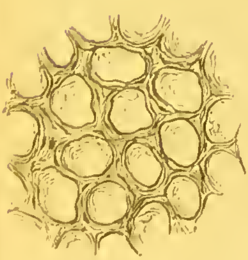
Fig. 46.

× 215
§ 101

Fig. 43.

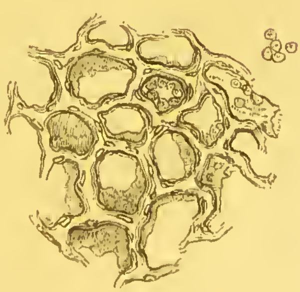
§ 102 × 215

Fig. 47.



§ 102. × 100

Fig. 48.



§ 102 × 100

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The so-ealled matrix deseribed and delineated by Goodsir, Kölliker, Dr. G. Johnson, and others, I have not sueeeeded in demonstrating to my satisfaetion; for, when the eapillaries of the kidney have been distended with transparent injeetion, I have failed to demonstrate any fibrous strueture at all resembling the drawings given of it, between the wall of the tube and that of the vessels. The appearanee eonsidered to be fibrous matrix is easily seen in any thin section of an uninjeeted kidney whieh has been washed and examined in water; but in sueh a seetion it is imposible to distinguish the walls of the tubes, those of the eapillaries, and the so-ealled fibrous matrix, from eaeh other. It has been figured by many as a distinet strueture; and Plate IX., Fig. 47, representing a seetion which has been washed in water, gives the appearanee most distinetly. The eapillaries are not injeeted, and, being eollapsed and shrunken, exhibit the fibrous appearanee which is eonsidered to depend upon the matrix. Fig. 48 represents an injeeted speeimen from the same kidney, whieh does not exhibit any indieation of fibrous tissue existing between the vessels and the tubes. The nuelei in the eoats of the vessels, and some nuelei external to them whieh are probably eonneeted with nerve fibres, are distinetly seen, but no fibrous matrix is observable. Here and elsewhere, as I have shown, the stretehed and erumpled eapillaries produee an appearanee resembling fibrous tissue or matrix of the kidney ("*Archives of Medicine*," No. III., 1858). A thin seetion of the eortieal portion of a kidney, whieh had been slightly washed in water, is also represented in Plate IX., Fig. 43. The vessels are not injeeted. *a*, eonvoluted portion of uriniferous tube; *b*, a portion of a tube stripped of its epithelium; *c*, outline of tube and crumpled capillaries, having a fibrous appearanee—the so-ealled matrix; *d*, very small Malpighian body. Loops of vessels shrunken, showing eells in their walls. × 215.

This so-ealled matrix has been compared to the ultimate ramifieations of Glisson's eapsule; and it has been eonsidered neeessary as a support to the struetures of whieh the gland is eomposed. I have never seen fibrous tissue in the situation deseribed in health in either gland; and it is quite obvious that the struetures do not require any supporting tissue, as they mutually support eaeh other; and any matrix would tend to inerease the distanee between the seereting eells and the blood; while we certainly find in these organs every arrangement to reduce this as far as possible eonsistently with

strength. If this matrix exists, it ought to be developed as a structure distinct from the tubes and vessels; but it has not been demonstrated at an early stage of development of the kidney or liver by anyone. In a careful examination of embryonic structures generally, one cannot fail to be struck with the absence of such fibrous or connective tissue, which is by some regarded as an essential part of every organ. It is at this early period that the tissues are softest, and seem most in need of support; and yet the embryonic structures are peculiarly destitute of any supporting fibrous framework whatever. The morbid changes are explained as well by supposing the formation of a new material between the walls of the tubes and those of the vessels, or by a thickening or other change in one or both of these structures, as by attributing them to an alteration in the matrix or intertubular areolar or fibrous tissue (*Bindegewebe*).

The conclusions to which I have arrived, from numerous investigations on this subject, may be summed up as follows :—

1. In the cortical portion of the kidney there is no evidence of the existence of a "*fibro-cellular matrix.*"

2. The fibrous appearance observed in thin sections of the kidney which have been immersed in water is due to a crumpled, creased, and collapsed state of the membranous walls of the secreting tubes and capillary vessels.

3. A small quantity of a transparent and faintly granular material, with distinct nuclei, the nature of which has not yet been conclusively determined, is alone to be demonstrated between the walls of the tubes and the capillary vessels.

4. The changes met with in disease can be fully explained without supposing the existence of a *fibrous matrix.*

103. On some Points connected with the Physiology of the Kidney.—The course of the blood has been fully described, and it has been shown how eminently adapted the Malpighian tuft is to facilitate the free escape of the watery parts of the blood. The influence of the nervous system upon the secretion of urine is well known. Nerves may be traced upon the large arteries, and followed on the small vessels for a considerable distance. I have seen nerves upon the Malpighian arteries which may be traced up to the tuft. I have not succeeded in demonstrating nerves in connexion with the capillaries of the tuft; but a careful examination of several specimens

has led me to conclude that these capillaries are supplied with nerves, as is also the case with the capillaries of the ciliary processes of the eye, and some other capillary vessels. In many cases, the so-called "connective-tissue corpuscles" external to capillary vessels, belong to exceedingly fine nerve fibres, which are only to be demonstrated with the utmost difficulty. I am now investigating the mode of distribution of the nerves to vascular structures, and I hope soon to be able to express myself more positively on these very interesting questions.

The appearance of some of the capillary vessels of the Malpighian tuft of the human kidney, separated and, to some extent, flattened out, is represented in Plate X., Fig. 49. The vessels were injected with dilute Prussian blue injection. The nuclei connected with their walls are well seen: *a*, a few coils separated from the rest of the tuft; *b*, part of a loop somewhat compressed, showing the nuclei a little flattened; *c*, tissue connecting the coils with each other, in consequence of which the globular form of the tuft is preserved, even when it is removed; *d*, a small portion of a capillary compressed as much as possible, showing the thickness of the capillary wall at the point of reduplication.

Collateral Circulation.—Virchow lays considerable stress on the existence of a collateral circulation through the vasa recta. He considers that the circulation in the medullary portion of the kidney is more free than it is in the cortex, because the blood in the latter region does not pass through Malpighian bodies. There can be no doubt of the correctness of Virchow's views upon this question, and I can confirm many of his statements from personal observation. Some years ago, in examining some specimens of diseased kidney, I was much struck with the thickness of the walls of some of the vasa recta in the pyramids. Upon further examination, these were found to exhibit the circular muscular fibres so characteristic of arterial walls. I have since carried out further investigations upon the healthy kidney, and have proved that many of the straight vessels running parallel with the tubes in the pyramids of the kidney are in reality small arterial branches with muscular walls. I suspect that some of these branches communicate very readily with the veins in the same situation; and it is not impossible that, in health, the blood may be caused to pass through the Malpighian bodies, or may be diverted, and, by passing through the vasa recta, be returned to

the veins more rapidly. This subject is one of very great interest, in connexion with the renal circulation.

In a state of health, the diminished rapidity of the circulation in the capillaries of the Malpighian body, consequent upon the greatly increased area of the capillaries, which the blood must traverse as it flows from the small artery, which alone supplies them, favours the transudation of water through the capillary walls. This fluid must at once pass into the uriniferous tube; and as it gradually traverses in succession the cells which line it, the soluble substances are dissolved out—the quantity of solid constituents gradually increasing as the solution passes down the tube, while the substances are being more fully oxidized at the same time. Now the blood just brought from the Malpighian body has parted with water, and, being more concentrated, is richer in *urinary constituents* than the blood in any other part of the kidney. This is conducted by the vessels into which the efferent vessel of the Malpighian body divides, to the upper part of a uriniferous tube below the Malpighian body. We should expect that the cells in this region would be more fully charged with soluble urinary constituents than those lower down the tube; and, in accordance with this view, we find that these cells are acted upon by the almost *pure water* which has just escaped from the capillaries of the Malpighian bodies; while, by the time the fluid has reached the cells at a lower point of the tube, it is already charged to a great extent with soluble constituents, and its solvent power is, of course, proportionately diminished.

Not the least important office of the cells lining the convoluted portion of the uriniferous tube is undoubtedly that of separating from the blood a considerable quantity of the *débris* of blood-corpuscles, in the form of *extractive matters.* It is almost certain that the cells have the power of altering some of the substances they separate from the blood, and converting them into these peculiar urine extractives. the physiological importance of which must be very great, as so large an amount is excreted.

Some observers have considered that special vessels are concerned in carrying blood to *nourish* the tissues of the gland, and Dr. Goodfellow thinks that the intertubular capillaries are concerned in this office. The quantity of blood passing into these vessels is, however, far greater than is required for the nutrition of the tissues of the kidney, and reasons have been already advanced for accepting the

view propounded by Bowmau with rcference to these capillary vessels. The tissues of organs gencrally, are nourishcd by the plasma present, and do not rcquire spccial vcssels. Many arguments may be adduced against the view, that the hepatic artery mercly scrves thc purpose of distributing blood to nourish the tissues of the liver, as is gcnerally supposed.

The views of Bowman, with regard to the office of the Malpighian body and the epithclium of the uriniferous tube, have bccn opposed by Ludwig, and more recently by Dr. Isaacs, in America, who tried to prove that the solid coustitucnts were separated by an epithelium, covering the capillarics of the Malpighian body (which, if it exists, is certainly very unlike glandular epithclium gcncrally, and the cells must be very much smaller than he has rcpresentcd); while, strange to say, he docs not attempt to show what office is pcrformed by that cnormous extent of epithclial surface in the convoluted portion of thc tube, or why the very peculiar relation betwcen the extcnsive system of capillaries arouud the tubes and that of the Malpighian body exists. Dr. Goodfellow thinks that the urinary constituents arc separated with watcr from the Malpighian capillaries, and that any constitueuts of the serum, or blood, that may have transudcd through their walls, "are absorbcd by the epithctical cells of thc tubules or by some other agents."* Therc docs not secm to be auy positive evidence that any constituents of the scrum do really transude through the Malpighian capillaries. The epithelium is not of the character of that we find usually concerned in absorption; and other objections might be urged against this view, cspecially certain facts observed in conncction with the urinifcrous or corresponding organs of some of the lower animals. It sccms to me, that Bowman's views on the physiology of the kidney arc supported by so many diffcrcnt arguments, that thcy will bc acceptcd by all who have carcfully studied the subject, from thc diffcrcnt points of view which hc has indicated. Many absolutely ncw facts must be discovered bcforc the conclusions which he arrivcd at cau bc rejcctcd.

104. On the Formation of Casts of the Uriniferous Tubes.— Such, thcn, being thc actions of the kidney in health, we may now consider briefly how thcse changes may be modificd iu ccrtain cascs. If the arterial walls were rclaxed, more blood would pass into thc

* "*Lectures on Diseases of the Kidney,*" p. 152.

Malpighian capillaries in a given time, and a great transudation of water would take place. If, on the other hand, the arteries became contracted, the secretion of urine would be diminished accordingly. Many sudden and temporary alterations in the circulation of the blood through the Malpighian bodies of the kidney undoubtedly depend upon an influence exerted through the nerves alone; but certain changes which are, unfortunately, of a more permanent character, are due to an altered action of the secreting cells. The rapidity of the circulation in the Malpighian body will be greatly influenced by the rate at which the blood traverses the capillaries around the uriniferous tubes; the flow of blood in these vessels being governed by the attractive force exerted by the cells within the tubes for the urinary constituents dissolved in the concentrated blood. Now if, from any cause, the action of the secreting cells became impaired, and they ceased for a time to exert their attraction for the constituents they ought to separate from the venous blood, a retardation to the circulation in these capillaries would result. This would affect backwards, as it were, the capillaries of the Malpighian tuft, in which the blood, urged on through the arteries, would tend to accumulate. Their thin walls, being much stretched, would not resist the passage of certain constituents of the blood; albumen and extractive matters would pass into the tube, and escape in the urine. Supposing this state of things to go on, the pressure on the Malpighian capillaries must necessarily increase; and these capillaries, distended to their utmost, and their walls stretched to the last degree, would at length burst, and all the constituents of the blood, including the blood-corpuscles, would pass into the tube, and would escape with the urine. The tenuity of the walls of the Malpighian capillaries, which permits the escape of water in health, will favour the escape of other constituents of the blood, and increase the chance of their rupture in disease, if they be exposed to increased pressure; but the collateral circulation already referred to in some measure counteracts such a tendency.

Professor Virchow has lately arrived at the conclusion that albumen and other constituents of the blood more frequently escape from the straight vessels of the pyramids than from those of the Malpighian bodies. According to this view, the constituents of the blood would have to pass through the walls of the tubes, as well as through those of the capillaries, in which case we

ought to find an œdematous condition of the kidney, and blood effused between the tubes more frequently than is the case. It seems to me that, before such a lesion was possible, the Malpighian capillaries must have become much thickened and altered in structure. In many chronic cases, as has been shown by Dr. Johnson, the Malpighian arteries become enormously thickened; and I have often observed the capillaries of the Malpighian body in a like condition; so that the permeability of their walls must be very greatly diminished. There can be no question that in many cases the blood-corpuscles and fluid matters escape from the Malpighian capillaries, for they may be seen in the convoluted portion of the tubes after death, and I have seen bodies extravasated from the vessels even in the capsule of the Malpighian body.

105. **Casts.**—In many cases of congestion, and in inflammation of the kidney, a spontaneously coagulable material is effused into the tubes, and coagulates there, forming a *cast or mould of the tube*, which is gradually washed out by the fluid which is secreted behind it, and thus it finds its way into the urine, from which it may be easily separated for examination.

A cast is composed of a coagulable material which is effused into the uriniferous tube; and, becoming solid there, it entangles in its meshes any structures which may be in that part of the tube at the time, and forms a mould of the uriniferous tube. The characters vary very much in different cases, according to the state of the tubes and the part in which the effusion of the matter takes place. Various substances are often entangled in the cast; and, by observing the character of these, we are often enabled to ascertain the nature of morbid changes going on in tubes at the time the cast was being formed. Great difference of opinion has been expressed with reference to the nature of the material of which the cast is composed. By some it has been termed fibrine; but the striated appearance always present in coagula of this substance is not found in the cast. Others have considered the cast was composed of albumen; but it is not rendered opaque by means of those reagents which produce precipitates in albuminous solutions. Not more than five years since, it was stated by two observers in France and Germany of high reputation, at least in other branches of scientific inquiry, that the cast really consisted of the basement membrane of

the uriniferous tube. How such a statement could be made by any one possessing even a slight knowledge of the anatomy of tissues, it is difficult to conceive.

The transparent material probably consists of a peculiar modification of an albuminous matter possessing somewhat the same characters as the walls of some epithelial cells, the elastic laminæ of the cornea, the walls of hydatid cysts, etc., but not condensed like these structures. I think it not improbable that these casts of the uriniferous tubes may really be composed of the material which, in health, forms the substance of epithelial cells. In disease, this substance, perhaps somewhat altered, or not perfectly formed, collects in the uriniferous tubes, and coagulates there. This receives some support from the fact that occasionally casts are formed although no albumen passes into the urine. According to this notion, it is possible that a cast might be formed quite independently of any congestion or morbid condition of the Malpighian tuft; but, as a general rule, there can be no doubt that serum escapes and albumen is found in the urine.

The diameter and general character of the cast will be determined by the state of the uriniferous tube at the time of its formation, as the researches of Dr. Johnson have indisputably proved. If the epithelium be abnormally adherent, the cast will be very narrow; if, on the other hand, the epithelium be removed, it will be of the width of the tube. Should the epithelium be disintegrating, the cast will afford evidence of the change. If in a state of fatty degeneration, fat-cells will be entangled in it. In hæmorrhage from any part of the secreting structure, blood-corpuscles are present; and, when suppuration occurs, the cast contains pus-corpuscles. When the transudation of the coagulable material occurs in a tube to which the epithelium is intimately adherent, or in a tube whose walls are smooth, the cast will be clear and perfectly transparent. The import of all these different characters is fully discussed in the works of Dr. Johnson; and several interesting cases, under observation for a considerable period of time, will be found reported in Dr. Basham's work.

The different forms of casts which are most frequently met with will be considered under the head of urinary deposits.

Professor Virchow thinks that casts are very constantly, if not entirely, formed in the straight portion of the uriniferous tubes; but

many of the facts already referred to strongly militate against this idea, aud it is common enough to see the casts in the tubes of the cortex. Morcover, as I have demonstrated in several cases, the cast receives successive layers upon its outer surface, as it passes down the tube ("*Illustrations*," Plates XIV. and XVI.). There is no doubt that casts are found in the *straight* as well as in the *convoluted* portion of the uriniferous tubes, but the value of the characters of the cast found in the former situation with regard to diagnosis cannot be questioned, while it is obvious that from casts found in the straight portion of the tubes we can learn nothing as to the nature of morbid changes occurring in the secreting part of the gland. In Plate X., Fig. 50, portions of casts from the convoluted portion of the tubes are seen embedded in transparent material. The drawing was taken from specimens found in the urine of a case of acute suppurative nephritis. It is probable that the small casts were found in the convoluted portion of the uriniferous tubes, and that the transparent material in which they were embedded, coagulated in the straight portion of the tube, near its opening, at the summit of a papilla. We may, therefore, conclude that casts are generally formed in the convoluted portion of the tube, although, in certain cases, the coagulable matter may be effused in the straight portion also, in which case the diameter of the cast will be very much greater than if it was formed entirely in the convoluted part of the uriniferous tube. In certain cases in which there is evidence of considerable irritation in the kidneys, sometimes so much as to lead one to suspect the existence of calculus in the kidney, a number of flocculent shreds may be passed in the urine. I have seen several cases in which these were composed of a very transparent and slightly granular material like ordinary mucus. In Fig. 83, Plate XVII., is represented such a cast which must have been entirely formed in the straight portion of the tubes. The ramifications from the larger mass extended into the fine tubes which open into the larger ones in considerable number. The drawing (× 75) was taken from specimens found in the urine of a patient under the care of my friend, Mr. Charles Hawkins, who had been suffering from renal irritation and affection of the bladder for many years.

106. **Circumstances under which the Urine may be altered in Quantity or Quality.**—In the remarks I am about to make, I

shall consider it as proved that the solid constituents of the urine are separated by the cells lining the uriniferous tubes, while the water filters through the walls of the capillaries of the Malpighian body. Diuretics may act in two ways—1. By causing increased transudation of fluid from the Malpighian tuft, in which case pale urine, containing very little solid matter, will escape in considerable quantity; 2. By causing the cells to separate from the blood, a larger amount of solid material, in which case a highly concentrated urine, rich in solid matter, will be secreted in greater proportion than in health. In certain diseases, there seems to be a tendency on the part of the kidneys to throw off morbid material which exists in the blood. If, under these circumstances, the flow of blood to the kidneys is not compensated for by rapid removal of these matters, congestion, perhaps running on to inflammation, occurs, and there is danger of serious damage to the organ.

It is in this manner that the albuminuria following scarlatina, and that coming on from exposure to cold, are to be explained. This subject has received full consideration from Dr. Johnson, in his work "*On Diseases of the Kidney*," and also in that "*On Cholera*." The action of many irritating diuretics is to be explained in a similar manner. A quantity of cantharides, which would do no harm to a strong healthy man with sound kidneys, would produce dangerous congestion and inflammation, with rupture of the capillaries of the Malpighian body, in a person who was recovering from an illness, or in one whose kidneys were affected by disease. In the one case, the secreting power of the cells appears increased by the action of the drug; while in the other they are incapable of effecting the increased amount of work suddenly thrown upon them, and the results above described must occur. Kramer and Golding Bird state that squill, capaiba, broom, juniper, and guiacum, cause the removal of an increased proportion of water from the blood, but do not influence the quantity of solid matter removed from the body in twenty-four hours. It seems probable that these remedies affect the capillaries of the Malpighian tuft, either directly, or perhaps more probably, through their action upon the nerves distributed to the renal vessels.

In cases where the blood is very watery, the excess of fluid is carried off by the kidneys; but at the same time, a greater amount of solid matter is removed in a given time, partly arising from the tissues being washed out by the large quantity of fluid, and partly

because the formation of urea, &c., is favoured by a dilute state of the fluids.

Many neutral salts (nitrates, sulphates, &c.) seem to increase the secretion of urine by being attracted from the blood in a state of solution, in all probability by the renal epithelium, the kidney being the channel by which they naturally leave the system. Urea has a similar diuretic action. Within certain limits, the greater the quantity of these substances in the blood, the more will be removed by the renal epithelium, supposing this to be healthy. The more strongly the epithelial cells be charged with urinary constituents, the greater the quantity of water required to dissolve them out This seems to be effected as follows :—When the urinary constituents are not removed from the cells by the water coming down from the tuft as fast as they are separated from the blood, they must accumulate until the surcharged cell ceases to exert that attractive force upon the blood in the capillaries around the tube which it does ordinarily. The tendency to stasis in the circulation thus caused necessarily interferes with the free passage of the blood through the Malpighian capillaries, and the increased pressure which results causes the escape of fluid into the tube, which washes out the solid matter accumulated in the cells. The latter resume their action, the circulation becomes free again, and the normal relation between the action of the cells of the tube and the Malpighian body is re-established.

Now alkalies, and especially the citrates, tartrates, and acetates, which become converted into carbonates in the system, increase not only the quantity of water removed from the system, but also materially augment the proportion of solid matter. These salts increase the quantity of urea and other matters formed. They seem to favour the conversion of the products resulting from the disintegration of tissue into these constituents. The action of such remedies is very desirable in a vast number of cases; and even where the kidneys are diseased, these salts act favourably.

A certain degree of dilution is necessary to ensure the diuretic action of many neutral salts. If the density of the solution be very great, exosmose of fluid from the blood will take place, and a purgative action will be produced. Certain salts may be made to act as purgatives or diuretics, according as they are diluted with a small or with a large quantity of water. The observations of Dr. Headland,

however, show that this physical explanation cannot be applied in all cases. That sulphate of magnesia is absorbed into the blood, at least in the majority of instances, there can be no doubt. It is often excreted in large quantity in the urine; and it is probable, as Dr. Headland suggests, that its *purgative action* is due to its removal, in the form of a weak solution, from the blood by the action of the intestinal mucous membrane.

The excretion of urine will also be materially affected by all those circumstances which influence the circulation in the kidney. There exists a compensating action between the cutaneous secretory surface and the kidneys. If a large quantity of water escapes in the form of sweat, the urine will be small in amount and highly concentrated; but if, from the effects of cold, there be scarcely any perspiration, the excess of fluid is entirely removed by the kidneys, and the solids of the urine are therefore held in solution in a much larger quantity of water. Pressure on the renal arteries, or on the aorta above their origin, will diminish the secretion of urine. Pressure on the veins, on the other hand, will first of all cause an increased flow of urine, and afterwards albumen will escape. In congestion of the liver and portal system, the amount of solids is greatly increased. It would appear that, in many cases, where the action of the liver is imperfect, and especially in some forms of organic disease, the kidneys, to some extent, perform the functions of the liver. In jaundice, both colouring matter and biliary acids are carried off in the urine. In this case, however, it must be borne in mind that these biliary constituents are formed by the liver, reabsorbed into the blood, and separated from it, as are many other substances abnormally present, by the kidney. In many affections of the liver, the urine-pigment is much increased; and it is probable that a certain proportion of material which, in a state of health, would have been converted into bile, is transformed into certain extractive matters and other substances, and eliminated in the urine. The crisis of many acute diseases is characterised by the presence of a large quantity of solid matter in the urine, and increased action of the kidney. Free sweating, and the secretion of a urine containing a large amount of urea and urates, in the course of many diseases, are often the earliest and most important indications of approaching convalescence. Dr. Golding Bird showed that abatement in the severity of the symptoms of ague was always associated with an increase in the amount of solid

matter in the urine. Now, in all these cases, it is obvious that the activity of the renal epithelium is increased. The separation of urinary constituents from the blood cannot be regarded as a mere percolation, but is dependent upon a vital property of the cells. It is probable that these cells take part in the actual formation of some of the urinary constituents, just as sebaceous matter is formed by the cells of the sebaceous glands, saliva by those of the salivary glands, &c. An alteration in the proportion of the water is rather to be attributed to temporary alteration in the calibre of the arteries which supply the Malpighian bodies, and to the variable pressure exerted by the blood as it traverses the Malpighian capillaries, depending, to some extent, upon the freedom with which it passes onwards into the capillary system, among the meshes of which the tubes lie.

107. On the Absorption of Substances at the Stomach, and their Excretion in the Urine.—The rapidity with which weak solutions are absorbed from the digestive organs, and secreted by the kidney, is marvellous. In Mr. Erichsen's well known experiments, it was shown that ferrocyanide of potassium could be detected in the urine within a minute after it had entered the empty stomach. These interesting conclusions were derived from experiments made on a case in which, from the deficiency of the anterior wall of the bladder and abdomen, the orifices of the ureters could be seen, and the urine collected as it trickled from them. A German suffering from this terrible malformation was in London in 1858, and many had an opportunity of seeing him, and observing how very soon, after a large quantity of water had been swallowed, the rate of the flow of urine from the ureters increased.

Anything interfering with the absorption of fluid from the stomach or intestinal canal will necessarily affect the secretion of urine. In various cases where the contents of the alimentary canal are in a condition unfavourable for absorption, but a very small quantity of urine is formed. Dr. Barlow has gone so far as to say that the seat of an obstruction in the intestine can be ascertained by noticing the quantity of water excreted in the form of urine. When close to the pylorus, it is stated that scarcely any urine is separated. In ordinary cases of what is known as sick headache, where, from temporary stomach derangement, little absorption occurs for some hours, no urine is secreted perhaps for twelve hours or longer. The

termination of the attack is marked by the very free and rapid action of the kidneys.

108. **Morbid Changes affecting the Structure of the Kidney.**—In cases where the blood which passes through the kidney is unhealthy, the secreting power of the renal cells is gradually impaired.

In cases of long continued wine and spirit drinking, this change probably results from an altered state of the blood engendered by the spirit, and not from its direct action, for there can be no doubt that large quantities of spirit may exist in the blood without producing any such change; and in all cases in which renal disease results from spirit drinking, the kidneys are by no means the only organs affected. In many instances most of the tissues of the body suffer more or less from a general change which has resulted from alteration in the blood. In advanced cases the cells of renal epithelium lose their healthy appearance, somtimes becoming smaller and condensed, sometimes appearing granular, as if undergoing disintegration. In consequence of the growth of the germs having been interfered with at an early period, the place of the disintegrated cells is not occupied by a new generation.

A complicated series of morbid changes in other structures of the kidney gradually ensues; and, in consequence of the blood being rendered still more depraved by the accumulation in it of matters which ought to be removed by the kidney, other organs suffer, and the changes continue to work on as it were in a circle. The coats of the smaller arteries become much thickened, the capillaries shrink, while their walls become thicker and often granular. The quantity of blood distributed to the organ diminishes; and many of the capillaries, being no longer required, shrink and cease to transmit blood. The diameter of the secreting tubes decreases, while the basement membrane is thickened and becomes more impervious. The whole organ becomes hard, and at the same time small and shrunken. This decrease in size takes place principally at the expense of the cortical or secreting portion of the kidney, as would be supposed. The Malpighian bodies waste. The remains of many may be seen without a capillary in them being pervious; and not a few of those which still exist are found to be so altered that they can hardly be recognised as Malpighian bodies at all. The greater part of the blood sent to the kidney passes into the pyramids by the *vasa recta*,

and soon re-enters the veins, a small quantity being distributed to those tubes and Malpighian bodies nearest the pyramids. The diminished amount of urea, &c., present in the urine, is probably separated in this latter situation; while a eertain quantity of water, with a little albumen and thc material of which the casts are formed, also escape in this situation, as well as from the straight part of the tubes.

But in such eases the vessels of the kidney are not the only vessels that are altered. The eoats of the arteries of the body gencrally, are more or less altcred. The smaller ones lose to a considcrable extent their eontractile power, and eease to be influenced by ehanges occurring in the nerves. Persons suffering from chronic renal discase, in an advanccd stage, cannot blush. The ealibre of the minute arteries is no longer affectcd by the nerves, and instantly altercd by any mental emotion, as in hcalth.

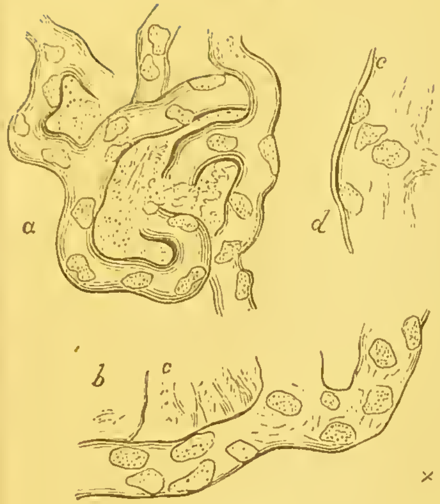
Long before the disease has arrived at this stagc, thc urinc will be found to contain a very small amount of solid matter, whieh eonsists principally of salts and extractivcs, with a very littlc urea.

By many pathologists these ehanges are explaincd by the effusion of inflammatory lymph, and subsequcnt thickening, eondensation, and eontraction of the so-eallcd *matrix;* but it seems to me that all the appearances observed may be much more simply aceountcd for, upon the view that thcy depend upon depraved nutrition and wasting, than by resorting to the hypothesis of the inflammation of a strueture whose existcnee has not becn satisfactorily demonstrated, and which, if it does exist, according to its warmest advoeatcs, only serves as a supporting tissue to the more esscntial elements of the gland-structure. It is very hard to see why such a tissue, which takes no active part in the changes going on in thc gland, should be the starting-point of all the serious morbid alterations which occur. Thc idea, I bclieve, has arisen from a supposed analogy betwcen cirrhosis of the liver and the so-called chronic inflammatory diseasc of thc kidney. Cirrhosis was eonsidered to depcnd upon inflammation, thickening, and subscqucnt eontraetion of anothcr supporting fibrous tissue (Glisson's capsule), which was supposed to surround thc lobules of the liver, and by its eontraetion to press upon the vessels. ("On Cirrhosis of the Liver," *Arehives of Medicine*, Vol. I., p. 118.) For the origin of these morbid ehanges, we must look to the altered actions going on in the seereting strueture, and not to inflammations

of tissues of doubtful existence, which take no part in the nutritive operations or gland-functions. The conclusions to which I have arrived from my own observations, with reference to the nature of the so-called matrix in the healthy kidney, and the changes taking place in disease, are at variance with those usually entertained both in this country and on the continent. The discussion of this question involves the whole subject of areolar tissue and its corpuscles. For an admirable statement of the opinions generally held, with many original observations, I must refer to a work by Arnold Beer, lately published in Berlin ("*Die Binde-Substanz der Menschlichen Niere*"). The drawings accompanying this work appear to me rather rough. The engraver, perhaps, has misinterpreted some of the author's representations.

Acute Nephritis.—The changes which I have described and figured in the kidney, in a case of acute nephritis, are of the greatest general interest. The case occurred in the practice of Mr. Image, of Bury St. Edmunds. The patient was 33 years of age, and was operated on for strangulated hernia. Four days after the operation, erysipelas appeared, which subsided in the course of three days. The day after the erysipelas disappeared, the urine which had hitherto been healthy, was found to contain albumen, blood-casts and blood corpuscles. The man died nineteen days afterwards, the *urine having been nearly suppressed for the last three days of his life.* There was anasarca but no disturbance of sensory or motor power, and no vomiting. The casts in the urine, three days before death, are represented in Plate X., Fig. 51, and in Fig. 52 a portion of a cast is shown, magnified 700 diameters. It contains in its *central part*, blood corpuscles and bodies like white blood corpuscles, which appear to be *undergoing multiplication* in the cast. The kidneys were much enlarged; one weighed 13 and the other 15 ounces. Now this considerable increase in weight was mainly due to the accumulation of matters in the capillary vessels and in the secreting tubes. The vessels were distended with large cells like white blood corpuscles (Plate X., Fig. 53), and the tubes were filled with casts and cells like pus corpuscles. Now, there can be little doubt that the cells represented in Fig. 53, in the capillaries, have been formed from the white blood corpuscles, and it is almost certain that the pus-like corpuscles in the *centre* of the cast have the same origin. The whole organ was passing into a state of suppuration, and the pus-like corpuscles in the urine of this

Fig. 49.



× 403

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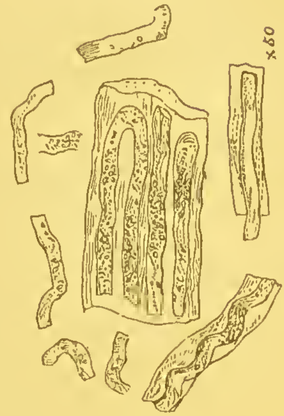
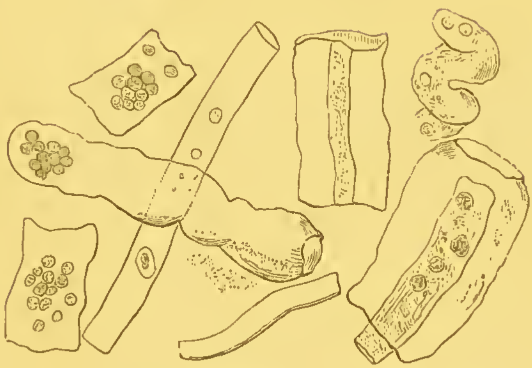
Fig. 50.



§ § 105, 371

Fig. 51.



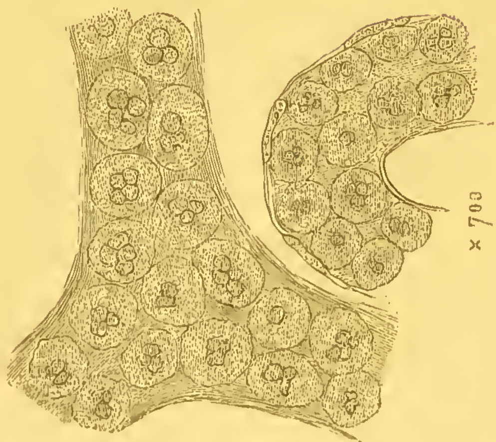
§ § 108, 371 × 215

Fig. 52.

× 700

§ 108

Fig. 53.



× 700

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To face page 68.

case probably resulted from the multiplication of corpuscles in the tubes which were produced by the white blood corpuscles. (See "*Archives of Medicine*," Vol. II., p. 286.)

Fatty degeneration.—In certain cases, the epithelium undergoes a very peculiar change, to which much attention has been given of late years. Fatty matter accumulates in the cells of the uriniferous tubes. The intertubular capillaries and those of the Malpighian bodies are also affected in a similar manner, and little collections of minute oil-globules may often be seen at intervals in their walls. This change often commences in a few of the tubes, and gradually extends until the whole organ is affected; but in some cases, only a few tubes here and there are affected by the disease, while many remain perfectly healthy. The kidney is in many instances much enlarged, while its colour has become very pale. Fatty degeneration, in many cases, is not confined to a single tissue or organ, but almost every part of the body is more or less involved.

109. Bright's Disease.—This term has been applied to all *morbid conditions of the kidney associated with albuminous urine.* Of late years, many important characters have been made out, by which we are enabled to distinguish several diseases of the kidney essentially different from each other—different in their origin, in their progress, and often in the results to which they lead. Dr. Johnson has accurately described several of these morbid changes, and his researches have been confirmed by other pathologists. However, some physicians still insist that the different conditions above alluded to are merely different stages of one and the same morbid process. Let any one examine carefully the small contracted kidney so commonly found in the bodies of old drunkards, with its rough puckered surface and diminished cortical portion, and contrast it with the large, smooth, and pale kidney, in a state of fatty degeneration, which is not unfrequently met with in young people not more than twenty years of age. The causes of these diseases are different; the conditions under which they occur are different; and although the result is fatal in both, death occurs in a very different way. Their chemical characters are different; their microscopical characters indicate the occurrence of changes which are totally distinct. Again, the treatment required in the early stages of these diseases, when alone any benefit is likely to be derived from treatment, is different.

The divisions and nomenclature adopted by Dr. Johnson are the following: *Acute desquamative nephritis; Chronic desquamative nephritis; Waxy degeneration of the kidney; Non-desquamative disease of the kidney; Fatty degeneration of the kidney; Suppurative nephritis.* Dr. Johnson still supports the same classification, and opposes the theory held by some pathologists with reference to the *oneness* of Bright's disease. He has recently written a paper on this subject, which will be found in Vol. xlii. of the "*Medico-Chirurgical Transactions.*" Dr. Johnson says, with regard to the oft debated question if large kidneys, at a subsequent stage of the morbid changes, contract, "The *rule* is, that a large Bright's kidney remains large to the end, and does not become a small one; and, on the other hand, a contracted Bright's kidney does not pass through previous stage of enlargement."

CHAPTER V.

Healthy Urine. *General Characters—Note-Book—Conical Glasses for examining Urine—Quantity of Urine—Colour of Urine—Smell of Urine—Clearness or Turbidity—Consistence—Deposit—Specific Gravity—Methods of taking the Specific Gravity—Reaction—Acid Urine—Alkaline Urine—Volatile and Fixed Alkali.*

In the present Chapter, the general characters of healthy urine, which are of the greatest interest in a clinical point of view, will be briefly described. It is very important that the observer should, at once, acquire the habit of recording the results of his examination; and I therefore strongly recommend everyone to keep a note-book.

110. Note-Book.—The result of every observation should be carefully entered in a *note-book* at the time it is made; and it is often of the greatest importance to make a sketch of the microscopical characters of a deposit, and to append a careful but short description of the specimen at the time the drawing is made, as well as notes of the case from which the urine was obtained. (On drawing and measuring objects, see "*The Microscope in its Application to Practical Medicine*," 2nd edit.; refer also to § 33, and to Plate V., Fig. 22, of the present Work.)

Now, suppose a specimen of urine brought for examination, how is the investigation to be commenced? What are the first points which should attract notice? In what order should they be observed? And how is the nature of the constituents which are dissolved in the fluid, or which form a visible deposit, to be ascertained?

The perfectly fresh urine should be poured into a conical glass vessel (Plates I. and II., Figs. 6, 7, 9, § 12). If any deposit is formed, it must be subjected to examination in the microscope

(Chapter III.), and certain chemical reagents must be applied, as described under the head of "Urinary Deposits." The chemical examination of the fluid will be described after the general characters of healthy urine have been considered.

111. **Quantity of Urine.**—It is very important in all cases to know the quantity of urine passed in a given period of time. The most minute chemical and microscopical examination often fails to show any fact of importance in the investigation of a case, in consequence of the quantity of urine passed in the twenty-four hours not having been measured. The practitioner desires to know, not only the quantity of urine passed (that is, water and solid matter together), but in many cases it is necessary to be acquainted with the absolute amount of solid matter dissolved in the water. For this solid matter consists mainly of substances resulting from the disintegration of tissues and blood corpuscles. Such information can only be obtained by carefully measuring the entire quantity of urine passed in twenty-four hours, and evaporating a given amount of the *mixed urines passed at different periods of the day* to dryness. From the result obtained, the entire amount of solids passed can easily be calculated.

The amount of urine and the proportion of solid matter it contains vary very much, from day to day, in healthy persons. The temperature of the air, and the amount of moisture present in it; the state of the skin and mucous surfaces generally; the activity of the functions of respiration and circulation; the amount of exercise; the quantity and nature of the food, and, of course, the amount of fluid taken—are some of the circumstances which affect the *quantity* of the urine passed. But the quantity of urine in health varies according to the size of the individual, or rather according to the weight and the activity of the nutritive changes, so that it is quite useless to put forward with confidence any definite amount as the average quantity of urine passed by individuals generally. The nature of the occupation also materially influences the amount passed. In round numbers, however, the proportion in health may be estimated at from twenty to sixty ounces; and a greater quantity is passed in the winter than during the summer months, because in cold weather less fluid escapes from the body through the skin. It is stated that rather more than two ounces of urine are secreted per

hour, but during some periods of the day the secretion is much more active than at others.

112. Colour of Urine.—Urine from the same individual varies much in colour at different times, and specimens taken from a number of persons in a state of health exhibit the greatest variation in tint. Nevertheless, important information is often gained by observing the colour of urine. In some cases, from the colour, we are led to suspect the presence of certain substances dissolved in the fluid; in others, we may feel sure that certain morbid constituents are not present. The colour of the urine, as well as many other characters, seems to be affected by the period of the day, the nature of the diet, the state of the respiratory process, changes of temperature, and many other circumstances. Healthy urine varies from a pale straw colour to a brownish yellow tint. In disease, it may be perfectly colourless, of a natural colour, bright yellow, pinkish brown, of a smoky appearance, blood-red, or even dark blue. What we learn from these differences in colour will appear when we come to consider the characters of the urine in disease. Urinary *deposits* also vary much in colour: they may be white, pink, red, pale or dark brown, blue or black.

The nature of the colouring matters of urine has been carefully investigated by Heller, who obtained a yellow colouring matter, *uroxanthin*—corresponding closely to vegetable indican. This substance was also detected subsequently by Dr. Schunk, of Manchester. Prout had obtained indigo from urine, and had sublimed it in 1840. Uroxanthin can be decomposed by acids, or even by exposure to the air, into a red colouring matter, *urrhodine;* and a blue substance, *uroglaucine.* The former has the same composition as *indigo red;* the latter, as *indigo blue* (C_{16} H_5 N O_2). Uroglaucine, analogous to the blue compound obtained from indigo, may be obtained from all specimens of urine, and, in disease, sometimes forms a visible blue deposit. Indigo blue has nearly the same chemical composition as hæmatine: it is, doubtless, formed from it. Leucine, which has also been met with many times in urine, is another substance which may be produced in the formation of this blue deposit of indigo. The yellow colouring matter of healthy urine was termed by F. Simon, of Berlin, *hæmaphæin.* The presence of a substance in the urine from which indigo can be obtained must now be regarded as a settled fact; and it is

probable that the blue deposit observed in certain instances, and referred to by different authors, was indigo blue, formed by the decomposition of uroxanthin. Dr. Hassall has published some interesting cases, and has very carefully analysed the deposit ("*Philosophical Transactions*," 1854, p. 297; "*Proceedings of the Royal Society*," June 16th, 1853). I can fully confirm his statements, as I have recently had an opportunity of examining a specimen of urine with blue deposit, which was sent to me by my friend Dr. Eade, of Norwich.* In this case, the deposit was crystalline.

Uroërythrine is another colouring matter described by Simon, and always associated with uric acid and urate of soda. This substance is probably the *rosacic acid* and *purpurate of ammonia* of Prout, and the *purpurine* described by Dr. Golding Bird. It has been analysed by Scherer, who finds that it contains about 65 per cent. of carbon. It would seem that, when the elimination of substances from the liver, rich in carbon, is interfered with, an increased quantity of this substance is excreted in the urine. A green colour has been noticed in certain cases (Parkes). Creosote and tar, when taken internally, sometimes cause the urine to be of a very dark colour. Dr. Harley finds that the colouring matter of healthy urine contains a notable quantity of iron, like the hæmatine of the blood; and he gives to it the name of urohæmatine. Prout believed that the colouring matter of urine was due to the presence of a sort of resin; and Dr. Harley has lately isolated a resinous substance, which possesses many characters in common with the resin derived from certain plants, and closely resembles draconine, which is obtained from dragon's blood, the exudation from the stem of one of the resin-bearing palms.

The relation of the colouring matters of the urine to those of the bile has been dwelt upon, and Berzelius long ago drew attention to the resemblance of the latter to the chlorophyll of plants. Certain chemical reagents cause the same change in both these colouring matters. A red colouring material is not unfrequently seen in the cells in the central part of the lobules of the liver, and Dr. Bence Jones met with a gall-stone of a brick-red colour. There is much reason for believing that the formation of these colouring matters is connected with the disintegration of blood-corpuscles, and the quantity formed and the intensity of the colour probably depend

* "*Archives of Medicine*," Vol. I.

upon the activity of the oxidising proeesses going on in the organism; but the wholc question of the produetion of colouring matter in the living body is still involved in great obscurity. The separation of a substance from the urine, from whieh indigo blue and indigo red may be prcpared, must be regarded as a fact of the greatest interest; aud further experimcnts on this subjeet are likely to lead to important results in eonnexion with the formation of organie colouring matters in the animal body. (*See* also § 210.)

113. Smell of Urine.—From the smcll of the urine, in some instances, the practitioner may gain uscful information. Healthy urine has a peeuliar and vcry characteristic smcll, which has been deseribcd as aromatic, but wcll known to all: it probably depends upon the presence of certain organic acids (Carbolic $C_{12} H_6 O_2$). In diseasc, thc specimeu may bc highly *pungent*, from thc presence of *carbonate of ammonia*, which is produced by the dccomposition of the urea cxcitcd by some animal fermeut, cspecially by mueus of thc bladder in a state of incipieut decomposition. In othcr instauces, it may have thc smell of hcalthy urine, but the odour vcry much more intcnse. Sulphuretted hydrogcn may be cvolved from it. Thc smell of the urinc is affected by many articles of food, such as asparagus, garlic, and cubebs. Turpcntine, even if inhalcd, causes the urinc to cvolve an odour something like the smell of violets.

114. Clearness of Turbidity.—Healthy uriue is perfectly clear and transparent; but, after it has bcen allowed to stand for a short time, a very faint, flocculcnt, bulky deposit collcets towards thc lower part of the vessel. This cloud consists of a little mucus, with impcrfectly formed epithelial cclls from thc mucous membrane, and epithclial *débris*.

In disease, the urinc may bc opaquc, from the prescnce of diffcrcnt substanccs held in suspcnsion. *Urate of soda* is the most frequent causc of this opacity, in which casc thc colour of thc mass is generally of a dirty ycllow, or brownish, rescmbling pcas-soup. Very rarcly it rcsults from fatty matter in a miuute state of division, and the urine has thc appearanec of milk. This occurs in cases of *chylous urine*. In thesc instanccs, the turbidity still continues after the urine has been allowed to stand still for some time; but gencrally the opacity of a specimen depends upou the prescnce of a deposit temporarily suspended in it from agitation, but which eolleets at the

bottom of the vessel after a time, forming a visible deposit, leaving a perfectly clear fluid above it.

115. **Consistence.**—Healthy urine is perfectly limpid, like water, and can be readily made to drop from a tube. In disease, however, the urine may be *slightly viscid*, or so *thick* and *glairy*, or *ropy*, that it may be drawn up at the end of a rod like a thread, and cannot be made to drop at all. It may be *semi-fluid*; and in rare instances, although passed perfectly fluid, it has afterwards assumed the form of a thick *firm jelly*, so that the vessel containing it might be inverted without its escape. Such specimens have been met with, associated with a milk-like appearance, in cases of *chylous urine.*

116. **Deposit.**—The only deposit which urine in health contains is the faint unimportant mucus-cloud before referred to (§ 114). All the constituents removed from the organism in this excretion, in health, escape in a perfectly soluble form; but when the healthy physiological changes are in any way interfered with, some of these constituents are produced in abnormal quantity, and are deposited, in an insoluble form, either at the time the urine is secreted, while it remains in the bladder, or at a variable interval of time after it has been passed. The deposit may be soluble in the warm fluid precipitated as soon as it becomes cold, or its deposition may be due to certain chemical decompositions occurring in the fluid.

117. **Specific Gravity: proportion of Solid Matter.**—By ascertaining the specific gravity of a specimen of urine (§ 23), we are enabled to form a rough estimate of the quantity of solid matter dissolved in the fluid; and, by measuring the entire quantity of urine passed in the twenty-four hours, we have data for judging approximately of the quantity of solid material removed from the organism in this secretion in twenty-four hours.

The specific gravity of healthy urine may be considered to be about 1,015, and the quantity of solid matter passed in the twenty-four hours, amounts to from 800 to 1,000 grains. It has been considered sufficient to calculate the quantity of solid matter from the specific gravity, by multiplying the number over 1,000 indicating the specific gravity, by about 2·5. The result will give an approximation to the quantity of solid matter in 1,000 grains of urine. This calculation is by no means correct, and is useless for accurate

investigations. Its inexact nature is shown by the fact that three very different numbers have been proposed, namely, 5·58, 2·33 and 1·65. When it is considered how widely different the composition of the solid matter may be in various specimens of healthy urine, it is obvious that results obtained in this manner must often be very wide of the truth. Take, for example, *albumen and common salt.* A fluid containing 136·4 grains of the former in 1,000 grains will have a specific gravity of 1,030; while one containing only 80·0 grains of common salt in the same quantity will have a specific gravity of 1,064. The proportion of common salt in urine varies more than the other constituents, as it depends upon the quantity taken in the food.

This clearly shows that any attempt to *calculate* the quantity of solid matter in an animal fluid cannot be very exact. In investigations, therefore, where any approach to accuracy is required, we must evaporate a given quantity of urine (1,000 grains) to dryness, at a low even temperature, and weigh the solid matter. As, however, this operation takes some time, physicians are compelled, as a general rule, to be content with taking the specific gravity. In many cases, the information gained by this simple operation is very important. Thus the urine may be not more than 1,002 or 1,003—a condition commonly met with in hysteria. A patient may be continually passing urine of specific gravity 1,010 to 1,012, which is commonly the case with albuminous urine, passed by patients suffering from certain chronic kidney diseases. Urine, containing a very large quantity of urea, so much that crystals of nitrate of urea are formed upon the addition of nitric acid without previous concentration *(excess of urea)*, usually reaches 1,030, or a little higher; and in cases of confirmed diabetes, where very large quantities of sugar escape from the organism, the urine has a specific gravity of 1,035 to 1,040, or even higher.

118. **Reaction.**—The reaction of urine may be readily ascertained by the use of litmus-paper, which is prepared by soaking a thin but firm smooth paper in an infusion of litmus. It is desirable not to use blotting-paper, or any spongy form of paper, for this purpose. Urine, having an *acid* reaction, immediately reddens this blue paper. The *alkaline* reaction of urine is ascertained by the use of *reddened litmus-paper,* prepared by adding a very small quantity of dilute

acid to the infusion of litmus. An alkali always restores the *blue* colour of this reddened paper. If no change occurs when the urine is tested with both kinds of paper, the reaction of the specimen is *neutral.*

119. Acid Urine.—The cause of the acid reaction of urine is obscure, and probably does not always depend upon the presence of the same substance. Sometimes the reaction may depend upon carbonic acid, which is present in greater or less proportion in all the animal fluids. In this case, the blue colour of the paper is restored by gently warming it after it has been changed by the acid. A fixed acid reaction may be due to the presence of an acid phosphate of soda—a salt which exhibits an acid reaction, without the presence of any free acid. This salt may be formed by the action of uric acid upon common rhombic phosphate of soda. If a little uric acid be added to a solution of common rhombic phosphate of soda, the mixture will, while cold, exhibit the characteristic alkaline reaction of the salt; but, when heat is applied, decomposition occurs; the uric acid disappears, and combines with one equivalent of the soda to form urate of soda; and an acid phosphate of soda is produced (experiment). The acid reaction of urine, however, cannot always be explained in this manner; and it is certain that traces of free organic acids are present. Lehmann has found both free lactic and free hippuric acids in some specimens of urine. Lately, Hallwachs has shown that a large amount of hippuric acid salts exists in healthy human urine.

Many specimens of urine which are slightly acid when passed from the organism, become more strongly so after standing for some days, and crystals of uric acid are deposited. The acid reaction may remain for weeks or even months, but usually the acidity gradually diminishes, and the specimen at last becomes alkaline from the presence of carbonate of ammonia, formed in consequence of the decomposition of the urea. The researches of Scherer have proved that the gradually increasing intensity of the acid reaction, and the deposition of uric acid, were due to a process resembling fermentation, which was excited by the presence of a small quantity of mucus.

The intensity of the acid reaction of urine in health is continually undergoing change at different periods of the day. Dr. Owen Rees,

in 1851, stated that "the degree of the acidity of the urine may, to a certain extent, be regarded as a measure of the acidity of the stomach" (Lettsomian Lectures, "*Medical Gazette*," Vol. XLVIII., 1851). Dr. Bence Jones has also made some highly interesting observations, which prove that the acidity of the urine alternates with that of the gastric juice. When the largest quantity of acid is being set free from the stomach, the acidity of the urine is at its minimum; and when the secretion of gastric juice is diminished, the urine exhibits a most strongly acid reaction. The urine passed just before each meal, or a long time after taking food, is intensely acid, while that which is secreted during the digestive process, for about three hours after a meal, is very slightly so, and in many instances it is decidedly alkaline. It is especially important to bear in mind the existence of these variations in the acidity of the urine in a state of health, and not to refer the intensely acid reaction of urine, secreted while no food is taken, to a morbid process requiring the exhibition of large doses of alkalies ("*On Animal Chemistry*," by H. Bence Jones, M.A., M.D., F.R.S.). Dr. Beneke has made upwards of one hundred experiments upon healthy and diseased persons without being able to confirm Dr. Bence Jones' observations. In only one case did he find the urine alkaline after meals. Sometimes the acidity was less, but this was not invariably the case. Nevertheless, he admits that the acidity of the whole amount of urine passed varied considerably, although he could not discover the cause. It seemed to be independent of the quantity passed, and was not affected by exercise or food ("*Archiv des Vereins für gemeinschaftliche Arbeiten zur Förderung der wissenschaftlichen Heilkunde*," 1 Band. 3 Heft.). Vogel, on the other hand, found that urine passed during the night was more acid than that secreted during the digestive process. Although the urine is by no means invariably alkaline, the acid reaction is always less intense after a meal. Dr. Roberts, of Manchester, has performed a very extensive series of experiments upon this question ("*Memoirs of the Literary and Philosophical Society of Manchester*," Vol. XV., 1859). He comes to the conclusion that, in two or three hours after a meal, the *acidity of the urine is diminished*, but that the secondary or remote effect of a meal is to *increase the acidity* of the urine. These results occur on an animal and also on a vegetable diet. Dr. Roberts considers that the above effects of the meal are due to the mineral constituents of

the food, which contain alkali in excess of the phosphoric acid present. Hence arises the alkalinity of the blood; but if this increases beyond a certain point, the kidneys separate the excess, and the urine is alkaline. If, on the other hand, the blood is not sufficiently alkaline, the kidneys separate acid. Thus do these organs regulate the quantity of alkali in the blood.

The intensity of the acid reaction is readily determined by ascertaining how much of a graduated solution of carbonate of soda is required to neutralise the acid in a given quantity of urine. In stating the results, the degree of acidity is expressed as if it depended on oxalic acid. In twenty-four hours, a proportion of acid is excreted which corresponds to from 30 to 60 grains of crystallised oxalic acid, according to Vogel.

120. **Alkaline Urine.**—The alkaline reaction of a specimen of urine may be due to the existence of carbonate of ammonia, in which case the blue colour produced by testing it with reddened litmus is destroyed by the application of a gentle heat (*volatile alkali*); or it may depend upon the presence of an alkaline carbonate, as carbonate of soda, or a neutral salt having an alkaline reaction, like common phosphate of soda, in which cases the application of heat does not restore the red colour of the litmus-paper (*fixed alkali*).

121. **Volatile Alkali.**—The development of carbonate of ammonia in urine depends upon the decomposition of the urea by the action of the mucus or some animal matter, which acts the part of a ferment. In some diseases of the mucous membrane of the bladder, and in cases of paraplegia, where the muscular coat of the organ is paralysed, and consequently the secretion is retained for a long time, this change is very liable to occur, and gives rise to pain and great distress, which are much relieved by washing out the bladder thoroughly with tepid water. A mere trace of urine which has undergone this change is capable of exciting a similar decomposition in a very large quantity. It is important to notice that if pus be present in such urine, it becomes coverted into a viscid glairy mass, which is removed from the bladder with the greatest difficulty. This action of the volatile alkali on the pus, precisely accords with that which occurs if ordinary liquor potassæ be added to a specimen of pure pus out of the body. Pus thus rendered glairy, forming a

viscid adhesive mass at the bottom of the vessel containing the urine, is usually called *mucus*, but as I have said, it really consists of altered pus. If this action on the pus only occurs after the urine has left the bladder, it is unimportant, but when it occurs before its expulsion, it is always necessary to interfere, and if the change cannot be entirely prevented, owing to the existence of certain mechanical impediments to the escape of the urine, we must try to render the urine acid, and thus prevent its occurrence, by giving very large and frequently repeated doses of nitric acid, unless this treatment is contraindicated, as in certain cases which I shall have occasion to refer to.

Whatever causes prolonged retention of the urine in the bladder, in the ureter, or pelvis of the kidney, will excite this change, and, as a consequence, roughening and ulceration of the mucous membrane ensue, with the precipitation of phosphate of lime and ammoniaco-magnesian phosphate. More pus is formed, which effects the decomposition of the urea and aggravates the mischief already produced, and unless relief be afforded, complete disorganisation of the mucous membrane results. Volatile alkali is never detected in healthy urine.

122. **Fixed Alkali.**—Urine, however, often exhibits an alkaline reaction due to the presence of an alkali which is not volatile by heat, and this reaction is often to be met with in a state of health. When an alkaline carbonate is detected in the urine, it usually results from the decomposition of salts of certain organic acids in the organism. Salts of tartaric, racemic, citric, and, under some circumstances, those of oxalic and acetic acids, become resolved into carbonates in their passage through the organism, just as by the influence of a red heat they are converted into carbonates out of the body. The urine may always be rendered alkaline, and very quickly so, by giving such salts in sufficient quantity; and their administration is of great advantage in cases where benefit is likely to be derived from alkalies, especially where strong alkalies do not agree with the digestive organs. I believe that in many cases the alkali thus formed in the organism exerts a more beneficial influence than the exhibition of alkalies or their carbonates. The value of the juice of oranges and lemons in various conditions is to be attributed to this change.

If the alkaline reaction of the urine is due to the presence of carbonate of ammonia crystals of triple phosphate ("*Illustrations*," Plate IX., Fig. 1; XXI., Figs. 1, 3), and a deposit of phosphate of lime in a granular state, or in the form of globules or minute dumb-bells, will be present; if, on the other hand, it depends upon fixed alkali, only the latter deposit without the crystals will be detected.

The quantity of alkali can be estimated by the ordinary process of alkalimitry. Dilute sulphuric acid containing a known quantity of pure sulphuric acid is added until the reaction is neutral to test paper.

Before resorting to a more complete chemical and microscopical examination of a specimen of urine, it is important to ascertain the *quantity* passed in twenty-four hours, to notice its *colour*, *smell*, *consistence*, *clearness*, or *turbidity*, and the presence or absence of a *deposit*, and to ascertain its *specific gravity* and *reaction*.

CHAPTER VI.

HEALTHY URINE. I. *Volatile Constituents.*—II. *Organic Constituents.*—III. *Inorganic Constituents*—VOLATILE CONSTITUENTS: *Water—Carbonic Acid—Ammonia and Ammoniacal Salts.* ORGANIC CONSTITUENTS: *Urea—Quantity—Characters—Circumstances affecting the Formation of Urea—Origin—Creatine—Creatinine—Guanine—Sarcine—Inosite—Uric Acid—Quantity—Detection—Mode of Formation—Urates—Hippuric Acid—Extractive Matters—Sulphur Compounds—Sugar—Mucus—Lactic Acid and Lactates—Oxalic Acid—Peculiar Organic Acids and Formic Acid.*

IT is convenient to divide the constituents of healthy urine into three classes, viz.:—

I. VOLATILE CONSTITUENTS;
II. ORGANIC CONSTITUENTS;
III. INORGANIC CONSTITUENTS.

The first class includes those substances which are volatilised at the temperature of a steam-bath (212° or less). The most important of these are, *water*, *carbonic acid*, and *certain ammoniacal salts*.

The second class contains those organic constituents which are not volatilised at a temperature of 212°, but which are decomposed at a red heat. The most important of these are, *urea*, *uric* or *lithic acid*, *hippuric acid*, with *urates* and *hippurates*, *lactic acid and lactates*, *mucus* from the bladder or other parts of the urinary mucous membrane; *creatine*, *creatinine*, and various indeterminate uncrystallisable substances included under the head of *extractive matters*. The *colouring matters* already described (§ 112), and certain

peeuliar organic acids, traees of *sugar*, with perhaps traees of *leucine*, *tyrocine*, and one or two other less important organie matters, might be ineluded in this elass.

In the third class are found various *saline matters* which remain fixed after the organic matter has been destroyed by a red heat, and the earbon which results, removed by prolonged exposure to a dull red heat in eontact with the air. These inorganie eonstituents consist prineipally of *chlorine*, *sulphuric* and *phosphoric acids*, and, in some cases, *nitric acid*, in eombination with *sodium*, *potash*, *soda*, *lime*, *magnesia*, *iron*, and sometimes *alumina*, with traces of *silica*.

I. Volatile Constituents of Healthy Urine.

123. Water.—Healthy urine contains from 940 to 960 grains, or even more, in 1,000. The proportion of water is much influenced by various eircumstanees, especially by the quantity taken in the food, the aetivity of the skin, and the presence of various substances which influence the chemieal changes going on in the tissues, or affect the secreting aetion of the kidneys. The mode of estimating the proportion of water has been before alluded to. At first this would be supposed to be a very simple matter, but in practice it is found to be one of the most difficult operations in analysis, because many of the organic constituents of urine are prone to undergo changes at a very moderate heat, and even at the temperature of the air, if the coneentration is effected too slowly. Praetieally, it is the best plan to eoneentrate the urine at a temperature of 100°, and then eontinue the evaporation *in vacuo* over sulphuric aeid until the residue eeases to lose weight (§ 10).

124. Carbonic Acid is held in solution in fresh urine: indeed, traces may be detected in all the animal fluids. Its presenee may be shown by passing some pure hydrogen gas through urine. After the gas has traversed the urine, it should be condueted into pure lime water, which will become turbid if there be an appreciable quantity of earbonie aeid present. This experiment is founded upon the fact that, if one gas be passed through a solution of another gas, the latter will be displaced by it. By distillation, also, the presenee of carbonie acid may be shown; but, in this process, great care must be taken

to prevent the production of carbonate of ammonia, which would, of course, cause a precipitation of carbonate in lime or baryta water. The fluid may be made to boil at a temperature of 120, if the air be exhausted. There are certain peculiar volatile acids which will be described with the other acids of the urine (§ 150).

125. Ammonia and Ammoniacal Salts.—Another volatile constituent of urine is *ammonia.* The presence of this substance in healthy urine has been doubted by many; but Heintz has shown that the addition of chloride of platinum to fresh urine causes a precipitate which consists of the potassio-chloride of platinum, with a certain quantity of the ammonio-chloride of platinum; the amount of the latter being estimated by determining the quantity of the potassio-chloride in a separate experiment. Neubauer has obtained thirteen grains of ammonia from the urine in twenty-four hours. Ammonia exists as urate and lactate; it is also found in combination with hydrochloric acid, with phosphoric acid and soda, and with phosphoric acid and magnesia. Chloride of ammonium is also present. Neubauer and Kerner estimate the quantity of chloride of ammonium at about 35 grains in twenty-four hours.

Ammonia is likewise given off during the decomposition of several of the organic constituents of the urine by heat, as indeed it is from many other nitrogenous organic substances. Thus, if a portion of the solid residue of urine be exposed to a temperature short of redness in a small glass tube, much very offensive vapour will be given off, and a carbonaceous residue will remain in the tube. If a piece of reddened litmus or turmeric paper, moistened with distilled water, be applied to the mouth of the tube as soon as it is heated, the blue colour of the former will be restored, and the latter will assume a dark brown tint—reactions which indicate the existence of volatile alkali or ammonia, which arises from the decomposition of nitrogenous matters.

II. Organic Constituents of Healthy Urine.

Many of the constituents of healthy urine may be obtained in a crystalline form by allowing a few drops to evaporate, at a moderate temperature (about 140°), upon a glass slide, or in a shallow oval glass cell. In this manner, crystals of urea, urate of soda, chloride of sodium crystallised in cubes and octohedra, phosphates, and sul-

phates, may be readily obtained. The observer should make himself familiar with the appearance of these crystals. (*"Illustrations of Urine,"* etc.; Urine, Plate I.)

The quantity of the organic constituents varies very much, as would be supposed. In healthy urine, about three-fourths of the solid matter consists of organic substances, and there may be found from 12 or 14, to 45 or 50 grains in 1,000 grains of urine. The mode of estimating the amount of solids has been already referred to (§§ 123, 10). The quantity of the organic constituents is easily obtained by burning a weighed portion of the solid matter, and by subtracting from the amount the quantity of saline residue which remains after incineration. The result gives the quantity of organic matter.

126. **Urea** (C_2 H_4 O_2 N_2).—The most important of the organic constituents of urine is urea. It is a crystalline substance, very soluble in hot water, and in four or five parts of cold water, soluble in alcohol, but insoluble in pure ether, deliquescent, readily crystallised if pure, but the presence of some organic constituents seriously interferes with its crystallisation. However, good crystals of urea may often be obtained by simply evaporating a specimen of urine upon a glass slide, at a moderate temperature. Urea has a cool saline taste, is perfectly colourless when pure, but has a very strong affinity for the colouring matter of urine. In order to obtain perfectly colourless urea from urine, it is necessary to expose it to the prolonged action of animal charcoal in a diluted state.

127. **Quantity.**—Urine in health contains from 12 or 15 to 30 or 40 parts of urea per 1,000; and as much as from 400 to 600 grains of solid urea are excreted from the body of a strong healthy man in twenty-four hours. The solid matter of healthy urine contains half its weight of pure urea. The amount of urea excreted in twenty-four hours, corresponding to each pound weight of the body, is about 3·5 grains. So that a healthy man, weighing about 140 lbs., ought to secrete during the twenty-four hours nearly 500 grains of urea. In infants and children, however, a much larger quantity in proportion to the weight of the body is secreted. From some calculations of Dr. Parkes, based on analyses made by Scherer, Rummell, Bischoff, and Lecanu, it appears that a child, weighing

about 30 lbs., and four years of age, will excrete for each pound weight of the body nearly 6 grains of urea in twenty-four hours.

The Rev. S. Haughton (a paper read before the Association of the King and Queen's College of Physicians, Dublin, 1860) has endeavoured to show that of the urea excreted certain proportions represent the *vital*, *mechanical*, and *mental* work performed in the organism. Men employed in ordinary routine bodily labour may be well fed on a vegetable diet, and discharge 400 grains of urea daily, of which 300 grains are spent in *vital*, and 100 grains in *mechanical* work. If the work is of a higher order, better food must be supplied, and 533 grains of urea are excreted. Of this quantity 300 grains are spent in *vital*, and 233 grains in *mental* work and *the mechanical* work necessary to keep the body in health.

128. **Detection.**—*Nitrate of Urea.*—The presence of urea is very easily detected, if the solution be moderately strong. If a few drops of strong nitric acid be added to urine which has been slightly concentrated by evaporation, and afterwards allowed to cool, a number of beautiful sparkling crystalline lamellæ immediately make their appearance. These crystals of *nitrate of urea* are not very soluble in the solution, and are easily recognised by their microscopical characters (Plate XI., Fig. 55). ("*Illustrations of Urine*," Plate III.)

Oxalate of Urea.—If, instead of nitric acid, a concentrated solution of crystals of oxalic acid be added to the concentrated urine, numerous crystals of *oxalate of urea* would be formed. The oxalate is also a very insoluble salt, and, like the nitrate, crystallises in rhomboidal plates; but the crystals are more perfectly formed, and the inclination of the angles is different (Plate XI., Fig. 56). ("*Illustrations of Urine*," Plate IV.)

A solution of pernitrate of mercury also forms a precipitate with urea; but, in order to apply this test, all the chloride of sodium and phosphates must be removed. Liebig has proposed a most simple and highly efficacious plan for estimating the quantity of urea by ascertaining the amount of a solution of pernitrate of mercury, of known strength, which is required to throw down the whole of the urea in a given volume of urine. This process for estimating the quantity of urea, as well as the simple plan proposed by Dr. Davy, has been described in § 39. Other plans of estimating urea have

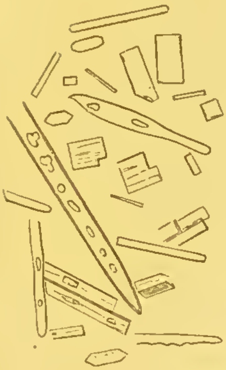
been proposed, but they are more complicated than those already described. Urea in solution is decomposed by nitrico-nitric acid, carbonic acid being rapidly given off. Draper's process is founded upon this fact ("*Phil. Mag.*," Vol. VI., Series IV., p. 290). Bunsen and Ragski have recommended other methods based upon the decomposition of urea into carbonate of ammonia. By ascertaining the quantity of carbonic acid or of ammonia formed, the proportion of urea can be calculated ("*Quarterly Journal of Chemical Science*," Vol. I., p. 420).

129. **Characters.**—Urea crystallises in four-sided prisms, which seem to be composed of a number of acicular crystals (Plate XI., Fig. 54). ("*Illustrations of Urine*," &c., Plate II., p. 56.) It melts at 248°, and is decomposed at a higher temperature; cyanate of ammonia and carbonate of ammonia being among the products of the decomposition. It is not decomposed by being boiled in pure water, but mere traces of putrescent animal substances excite rapid decomposition even in the cold. Yeast also exerts the same effect; and mucus and pus produce this decomposition very rapidly, as already remarked under the head of "volatile alkali" (§ 121). The rapid evolution of carbonate of ammonia from urine which has been placed in a dirty vessel, is explained in the same manner.

It is curious that urea causes common salt, which, under ordinary circumstances, crystallises in cubes, to crystallise in octohedra; and chloride of ammonium, which crystallises in octohedra, to crystallise in cubes.

In the laboratory, urea may be formed artificially. By allowing cyanate of ammonia to evaporate to dryness, it becomes converted into urea, in which neither cyanic acid nor ammonia can be detected. Urea is one of the products formed by the action of peroxide of lead on uric acid, and it is also produced by the action of alkalies upon alloxan and creatine. Béchamp stated that he had obtained urea directly from the action of oxidising substances on protein compounds, as permanganate of potash upon albumen. This experiment has been many times tried in my laboratory without success, and several chemists have failed to confirm Béchamp's results; so that we may consider that, up to the present time, no one has succeeded in producing urea directly from the tissues, or from albuminous substances.

Fig. 54.



§ 126 × 215

Fig. 55.

§ § 128, 203 × 215

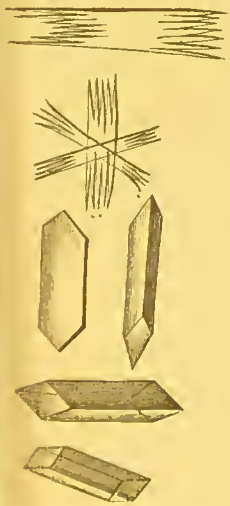
Fig. 56.

§ 128 × 215

Fig. 57.

§ 135 × 215

Fig. 58.



§ 140

Fig. 59.

§ 132

Fig. 60.

§ § 134, 321

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If it is desired to obtain a specimen of pure urea from urine, an *oxalate or nitrate* is first prepared, purified by being recrystallised, dissolved in water, and heated for some time in contact with pure animal charcoal. When the solution is colourless, it is decomposed with chalk or carbonate of barytes. The urea is separated by alcohol, and the solution concentrated, so that crystals may form. The pure crystals are very deliquescent; but they may be dried and preserved for any length of time, if carefully excluded from the air. They form beautiful microscopic objects.

Rich in nitrogen, very soluble in water, readily diffused through large quantities of fluid, and possessing considerable power of permeating animal membrane, urea may be regarded as the principal product resulting from the disintegration of nitrogenous tissues, (probably immediately from the red blood corpuscles), and as one of the most important excrementitious substances from the animal organism. Not only is urea derived from the products resulting from the disintegration of muscular fibre, but any excess of albuminous materials taken in the food is removed from the body chiefly in the form of urea. It must, however, be borne in mind, that the urea does not exist in the fluid expressed from the muscles: it is probably formed in the blood.

130. Circumstances affecting the Formation of Urea.—The quantity and nature of the food, and all circumstances which affect the nutrition and repair of the tissues, will exert an influence upon the quantity of urea formed in a given time. A liberal diet, rich in albuminous substances, and active exercise, combined with a healthy state of the organs of respiration and circulation, cause the formation of a large quantity of urea; while indolent habits, a diet rich in carbon and poor in nitrogen, insufficient food of any kind, an unhealthy state of the lungs and circulatory organs, and an imperfect supply of good air, will diminish the proportion formed. It need hardly be said that a greater quantity of urea is formed during the day than during sleep; by strong muscular persons, than by weak ones; by men than by women; in winter, when a small quantity of excrementitious substances are removed by the skin, than in summer, when the perspiration is abundant.

In all probability, urea is formed in the organism by the oxidation of uric acid and other substances. If the oxidising

processes in the body are active, these substances become ultimately resolved into urea and carbonic acid; but if, on the other hand, these processes are less active than they should be, the uric acid does not undergo further decomposition. A certain quantity of oxalic acid, and other substances of a lower degree of oxidation than urea, seem to be produced, and instead of the greater part of the comparatively insoluble uric acid being resolved into soluble urea, an increased quantity is found in the urine. Wöhler and Frerichs have shown that, if uric acid be taken at night, oxalate of lime is found in the morning urine; and Neubauer found that, when rabbits were made to take a considerable quantity of uric acid with their food, the urea in their urine increased from 1·34 to 4 grammes (from 20·67 to 61·72 grains). Large quantities of fluids cause an increase in the proportion of urea formed in the organism. A dilute state of the solids is favourable to their oxidation; and in certain conditions, where these changes are but imperfectly carried on, and in consequence uric acid accumulates in the blood, or at most is resolved into oxalic acid, the further oxidation is promoted by the administration of increased quantity of fluid, especially of fluids containing alkalies which not only increase the activity of the changes, but effect the solution of the insoluble uric acid and urates. Hence the benefit of alkaline waters, baths, moderate exercise, and plenty of good air, in gout and other conditions in which much more uric acid is formed than can be, under ordinary circumstances, converted into urea.

The quantity of urea excreted is also increased by common salt (Bischoff). It is probable that not only does cloride of sodium, so to say, filter through the different tissues, like other saline substances, and thus drive out other materials which are contained in their interstices; but that it also facilitates the occurrence of chemical change in the body, and directly influences the quantity of urea formed. The importance of chloride of sodium in cell-growth, during the development of different textures, and its value in nutrition generally, are well known.

The beneficial effect of alkalies in different cases is acknowledged by all; and it is probable that this is in part to be explained by the influence they have been proved to possess in promoting chemical change in the body, and especially in favouring the oxidation of albuminous substances. Dr. Parkes has shown conclusively, in an elaborate series of experiments, that liquor potassæ exerts a direct

influence of this kind. ("On the Action of Liquor Potassæ on the Urine in Health," *British and Foreign Medico-Chirurgical Review*, Vol. XIV., p. 258, January, 1853.) The per centage of solids in the urine is increased, the urea seemed to be increased somewhat; but Dr. Parkes considers this only a probable effect of the alkali. The proportion of sulphates was augmented in all the experiments. Franz Simon long ago showed that the sulphates were always increased whenever an increased proportion of urea is formed; and the more recent researches of Dr. Bence Jones lead to the same conclusion. In Dr. Parkes' experiments, the acidity of the urine was hardly affected by the liquor potassæ; and the whole of the potash taken (2 drachms) was entirely excreted in the urine, in the form of sulphate, in a very short time,—if taken on an empty stomach, in from thirty to ninety minutes. Such facts assist in the most important degree to elucidate some of the most complicated chemical changes going on in the organism, and afford valuable information as to the nature of various morbid changes, as well as suggest the means by which these may be modified or counteracted. For these reasons, I have thought it desirable to dwell upon them rather at length.

On the other hand, both the solids (urea, extractives, uric acid, sulphuric acid by 13 grains, daily phosphoric acid, chloride of sodium very considerably), and fluid of the urine are diminished by alcohol; so also is the proportion of carbonic acid exhaled. Tea causes a diminution both in the quantity of urine and fæces, as the beautiful researches of Dr. Böcker have conclusively proved. ("Beiträge zur Heilkunde Vol. I.," *Medico-Chirurgical Review*, Vol. XIV.) Hammond's observations confirm Böcker's in the most important particulars ("*American Journal, Medical Science*," October, 1856). Coffee exerts a similar effect, which seems to be due, not to the caffeine, but to the empyreumatic oil which it contains, according to Julius Lehmann. These substances, tea, coffee, and alcohol, in moderate quantity, affect the disintegration of tissue, and directly diminish the quantity of the excrementitious substances formed in the process. Supposing the food to be insufficient, the loss of weight which must necessarily take place in the body would be lessoned; and they may, therefore, be regarded as advantageous, not only in economising the food, but in limiting to some extent the waste of the albuminous tissues. Probably these substances directly interfere with the disintegration of the blood corpuscles.

131. Origin.—It has been concluded that urea is not formed in the kidneys, as it has been shown to exist in the blood. It is merely selected or separated from this fluid by the cells of the uriniferous tubes. At the same time it must be admitted, that it has not been proved, that no urea whatever is found in the kidneys. It is with difficulty detected in healthy blood, because it is prevented from accumulating in that fluid in sufficient quantity by the selective power of the renal epithelium.* If, however, the secreting action of the kidneys be impaired by disease, or if the blood be prevented from flowing through them, the urea will accumulate in the blood to a considerable extent, interfering with the function of other organs, especially the brain; and may in many cases be very readily detected by chemical tests.

Under these circumstances, an incomplete removal of the urea will take place through other channels. It has been detected in the fluids of the intestinal canal, in vomited matters, in the saliva, tears, milk, bile, and sweat, in serous fluids in different localities, in the liquor amnii, and in the fluids of the eye.

Urea cannot be detected in the muscles, but can be readily produced from several substances found in them; and it is therefore probable that, in the organism, urea forms the last of a series of compounds which results from the disintegration of the tissues, or more immediately from the disintegration of blood corpuscles. Removed from the body, very slight causes are capable of effecting its decomposition, and resolving it into ammonia and carbonic acid—substances of the highest importance to the growth of plants.

It has been generally concluded that any albuminous matters taken in the food, in excess of what is required for the nutrition of the system, is at once converted into urea. Bischoff and Voit have endeavoured to show, on the other hand, that in this and in all cases the urea results from tissue metamorphosis. It seems to me most probable that all pabulum entering the system must, before its elements can be applied to the nutrition of the tissues or be removed by the organs of respiration and secretion, be first of all taken up by cells (chyle corpuscles, white blood corpuscles), and become living or *germinal matter*, which, after passing through certain definite

* Dr. Thudichum attributes the failures of observers to detect urea in the blood, to their precipitating the albumen by heat. If the blood be treated with strong alcohol, the urea is dissolved, and the albumen rendered insoluble at the same moment. The former can be detected in the alcoholic solution.

stages of existence, becomes the *formed* matter of the red blood corpuscles. The products resulting from the disintegration of this formed matter may be taken up by the germinal matter of tissues, and at length become tissue, or by that of secreting cells, in which case it is removed from the body altogether.

132. **Creatine** ($C_8H_9N_3O_4$) exists in small quantity in urine. Its presence in this secretion was discovered by Heintz. Dr. Thudichum has obtained from 3·45 to 6·32 grains of creatine from the urine of a healthy man in twenty-four hours. The average is 4·7 grains. Creatine has a pungent taste, is very soluble in hot water, but requires about seventy-five parts of cold water for its solution. It is very slightly soluble in alcohol, and quite insoluble in ether. It crystallises in right rectangular prisms and rhomboidal crystals. ("*Illustrations of Urine*," Plate VII., Fig. 3.) By being boiled with baryta water, it is converted into urea and sarcosine; with strong acids, into creatinine.

Creatine may be obtained from urine by the following process, proposed by Liebig. Lime water and chloride of calcium are first added to the urine, which is then filtered and concentrated by evaporation, in order to remove most of the salts. The liquid from which the salts have been separated is decomposed with one-twenty-fourth of its weight of a syrupy solution of chloride of zinc. After the lapse of some days, a number of round granules made their appearance. These consist of chloride of zinc and creatinine, with which creatine is mixed. ("*Illustrations of Urine*," Plate VII., Figs. 1 and 2.) They are dissolved in hot water, and treated with hydrated oxide of lead until the reaction is alkaline. The oxide of zinc and chloride of lead are to be removed by filtration; and, after being decolorised by animal charcoal, the solution is evaporated to dryness. The residue is to be treated with boiling alcohol, which dissolves the creatinine very readily, but leaves the creatine, which may be recrystallised by solution in hot water. Crystals of creatine are represented in Plate XI., Fig. 59.

Creatine is obtained from all kinds of lean meat, but exists in larger proportion in that of mammalia than in birds, reptiles, and fishes. Gregory obtained ·14 from 100 parts of bullocks' heart, ·08 in 100 parts of pigeons' flesh, and 0·6 in the same quantity of the flesh of the skate. Although the flesh of fishes contains less creatine

than that of the higher animals, it is more favourable for extraction. I obtained more than seventeen grains of creatine from two pounds of the flesh of the crocodile. The presence of creatine has been detected in the blood by Verdeil and Marcet. Traces of it have been discovered in the amniotic fluid.

Its existence in the juice of muscular tissue, and its presence in the urine, would lead to the conclusion that creatine was one of the nitrogenised products resulting from the disintegration of muscular tissue; and such a view of its nature is supported by the readiness with which it is decomposed into urea, creatinine, and sarcosine. It is found in greater quantity in muscles which have been in active exercise during life, than in those which have been quiescent. The heart yields a large quantity; and more is found in animals which have been hunted to death than in those destroyed without being subjected to violent exercise. Creatine may, like urea, be regarded as an excrementitious substance.

133. **Creatinine** ($C_8H_7N_3O_2$) is also crystalline. The crystals take the form of right rectangular prisms, according to Robin and Verdeil. It has a strongly alkaline reaction, and is soluble in water. It is very soluble in warm alcohol. It combines with different acids to form salts. With chloride of zinc a crystalline compound is formed, composed of roundish wart-like masses, made up of minute radiating crystals, which have been already referred to.

Creatinine is found in the urine in larger proportion than creatine, and must be considered as an excrementitious substance. It is not destroyed in the decomposition of urine, while the creatine undergoes conversion into creatinine. Dr. Thudichum obtained as much as from five-and-a-half to nearly ten grains of creatinine from the urine of a healthy man in twenty-four hours.

134. **Guanine** ($C_{10}H_5N_5O_2$), **Sarcine, Inosite** ($C_{12}H_{12}O_{12}+4Aq.$).—Strahl and Lieberkühn have discovered a substance in urine which they considered to be xanthine, but which, from its behaviour with reagents, may probably be regarded as guanine. Strecker has detected in urine a substance closely resembling sarcine, found in muscular fibre; but its exact nature is at present doubtful. Inosite has been found in the urine of a man suffering from Bright's disease by Cloëtta, but it has not yet been detected in healthy urine. Crystals of inosite are represented in Plate XI., Fig. 60.

135. Uric or Lithic Acid ($C_{10}H_4N_4O_6$).—The organic constituent of the urine which ranks next in importance to urea is uric or lithic acid. In healthy urine its presence cannot be detected, unless a small quantity of a stronger acid, as nitric or hydrochloric, be first added to decompose the soluble urates. After the mixture has been allowed to stand for some time, the uric acid separates in the form of small red crystalline grains, which adhere to the sides of the glass vessel. Upon microscopical examination, these are found sometimes to be composed of separate crystals, and sometimes of small stellate groups; the individual crystals varying in form from the lozenge-shape to that of an elongated crystal with sharply pointed extremities. ("*Illustrations*," Plate IV., Figs. 2, 3, 4, and 5.) Uric acid is a very weak acid, and is perfectly separated from its salts by acetic acid. It is soluble in solutions of alkaline lactates, acetates, carbonates, phosphates, and borates. Uric acid has the power of decomposing the alkaline phosphates. It takes a part of the base, forming a urate, and leaves an acid phosphate, as I mentioned when speaking of the acid reaction of urine. The colour of the crystals of uric acid which have been obtained from urine is derived from the proper colouring matters of the secretion, and must, therefore, be regarded as an impurity. It can easily be obtained perfectly pure and colourless; and, in three or four instances, I have observed perfectly colourless crystals of this substance, which have separated spontaneously from urine holding in solution scarcely a trace of colouring matter.

Pure uric acid crystallises in the form of very thin rhomboidal laminæ; but the sides of the crystals, instead of being perfectly straight, are usually more or less curved. The angles, again, are often rounded, so that the crystal has an oval form. In Plate IV., Figs. 2 and 5, and Plate V., Fig. 7, of the "*Illustrations*," some pure crystals of uric acid are represented. Some of these crystals were obtained by the addition of acid to the solution. Although uric acid may be perfectly pure, the crystals vary much in size and form (Plate XI., Fig. 57). Experiments show what very slight variations in the conditions under which they are produced are sufficient to determine great alterations in the form of the crystal.

136. Quantity.—Healthy urine contains from half a grain to a grain of uric acid in 1,000 grains of urine. The solid matter contains

about 1·3 per cent. of this substance, and probably from five to eight grains are excreted by a healthy adult man in twenty-four hours. Dr. Thudichum gives the latter as the average quantity. The quantity of uric acid excreted in twenty-four hours, for every pound weight of the body, amounts to ·059, according to Parkes.

137. **Detection.**—The chemical characters of uric acid are well marked.

1. If to a deposit consisting of uric acid, placed on a glass slide, a drop of nitric acid be added, a brisk effervescence ensues; and when the mixture is slowly evaporated over a lamp, a reddish residue is left. Upon the addition of a drop of ammonia, a rich purple tint is produced, owing to the formation of murexide, the so called purpurate of ammonia. This test is exceedingly delicate: it was first applied by Dr. Prout. One other substance possesses a similar reaction, and this is caffeine; but uric acid is at once distinguished from it by its microscopical characters.

2. The deposit suspected to contain uric acid or a urate may be dissolved in a drop of solution of potash, in which it is very soluble. Upon adding excess of acetic acid, and leaving the mixture for some hours, small crystals of uric acid will form. These may be recognised by their microscopical characters.

3. Uric acid may be detected in animal fluids, when mere traces of this substance or of urates are present, by a plan proposed by my colleague (Dr. Garrod). The fluid suspected to contain the urate is treated with a few drops of strong acetic acid (glacial acetic acid is best) in a watch glass. A few filaments of tow or very thin silk are placed in the mixture, and the whole set aside under a glass shade in a warm place, for twenty-four or forty-eight hours. Gradually uric acid crystals separate, and are deposited upon the filaments. Their characters may be recognised by microscopical examination. Some crystals of uric acid upon a hair are represented in Plate XXI., Fig. 6, of the "*Illustrations.*"

The quantity of uric acid is estimated by collecting the crystals separated by the addition of an acid, and weighing them after they have been carefully washed and dried. Dr. Thudichum recommends the use of nitric acid, because the uric acid is less soluble in it, and there is not so much tendency to the development of fungi as if hydrochloric be employed.

138. Mode of Formation.—Uric acid is found in the urine of most carnivorous animals, and in that of young herbivora while sucking, and, therefore, feeding upon a diet rich in nitrogen. It is not found in the urine of the pachydermata, not even in that of the omnivorous pig. It is abundant in the urine of birds, and is found in that of many reptiles and insects. Uric acid exists in the blood, and is only *separated* from that fluid by the kidneys. Dr. Garrod has detected it in the blood of men in health, and in cases of gout in considerable quantity. In such instances, uric acid crystals may be separated from the fluid obtained from a blister, according to the plan just described. It has been detected in the juice of the spleen in considerable quantity by Scherer, but Mr. Gray has failed to confirm these observations. Cloëtta has found it in the pulmonary tissue of bullocks' lungs, associated with taurine, inosite, and leucine. It has also been found in the brain and in the liver.

Uric acid, like urea, is one of the products indirectly resulting from the disintegration of albuminous tissues. It is probable that it results directly from the action of oxygen upon substances formed by the red blood corpuscles. The formation of a large quantity of uric acid by birds is a fact strongly in favour of Liebig's doctrine, that uric acid is first produced, and that this is afterwards converted into urea. Prout held "that a very large proportion of the urate of ammonia found in the urine on common occasions appears to be developed from the imperfect albuminous matters formed during the assimilating processes." This is rendered probable by the researches of later observers, especially by those of Bidder and Schmidt. Uric acid may be deposited, in combination with soda and lime, in various structures. It may accumulate beneath the skin, so as to form large collections, which are familiar to us under the name of chalk-stones. It is curious that these depositions should take place in areolar tissue, in white fibrous tissue, and in connexion with cartilage. Perhaps this may be connected with the very slight vascularity of these tissues when fully formed, although they are highly vascular during the early period of their growth; and it must be borne in mind that the deposits usually occur at a time of life when they are fully developed, after which they probably undergo very slight changes, and the processes concerned in their decay and regeneration are slowly and, perhaps, in sedentary

persons, very imperfectly carried on. These circumstances would favour the separation of a slightly soluble substance from the blood, and its deposition in an insoluble state. Lehmann has shown that, after attacks of disturbed digestion, the proportion of uric acid to the urea becomes increased. Alcoholic liquors seem to have the same effect. In normal conditions of the system, the urine contains about 1 part of uric acid to 28 or 30 parts of urea; but, under the circumstances just mentioned, the ratio becomes 1 to 23 or 26. This increased proportion of uric acid appears to be formed in consequence of the usual proportion not being converted into urea. Alcohol causes a diminution in the quantity of carbonic acid exhaled; and, in such cases, an increased proportion of uric acid, urates, and usually oxalates, is found in the urine.

A highly nitrogenised diet, with insufficient exercise—confinement in ill-ventilated rooms—all circumstances interfering with the healthy action of the respiratory apparatus—or preventing the proper amount of blood being carried to the pulmonary surface, active exercise in confined air, &c.,—are conditions favourable to the formation of an increased quantity of uric acid and urates. The formation of urea and oxalic acid from uric acid in the organism, or artificially by the action of peroxide of lead, has been previously alluded to. Ranke has shown that, at a high temperature, in the presence of yeast and an alkali, uric acid also becomes converted into urea and oxalic acid.

139. **Urates.**—Uric acid is separated from the blood by the kidneys, in the form of a urate, which is readily soluble in water. After its separation, however, this salt may soon undergo decomposition, and insoluble uric acid will be deposited. In the majority of cases, this decomposition does not take place until after the urine has left the bladder; but sometimes it occurs in the bladder itself. The causes of the precipitation of uric acid are well worthy of attentive study, as they are intimately connected with the formation of uric acid calculi. The quantity of urates in healthy urine is very small, but not unfrequently enough is present to form a very abundant deposit after the urine has been allowed to stand for some time. I propose to describe the characters, and allude to the composition, of these salts, when the subject of urinary deposits is brought under notice.

140. Hippuric Acid ($HO,C_{18}H\,NO_5$) was first detected in horses' urine by Liebig, and was proved by him to exist in healthy human urine in small quantity—a statement which has been confirmed by Lehmann, and recently by Kühne and Hallwachs. It is not found in the urine of carnivorous animals, but among herbivora it occurs in considerable quantity. It does not exist in large quantity in the urine of calves while sucking, but cows' urine contains as much as 1·3 per cent. Lehmann has detected it in considerable quantity in the urine of the tortoise (*testudo græca*).

Hippuric acid is soluble in about six hundred times its weight of cold water. It is very soluble in hot water, and also in alcohol, but is insoluble in ether. It crystallises very readily in various forms, which are derived from the right rhombic prism (Plate XI., Fig. 58; "*Illustrations of Urine*," Plate IX., Fig. 1). It is very easily decomposed into benzoic acid, especially in the presence of extractive matters, and other constituents of the urine. In testing for this substance, the perfectly fresh urine only should be employed. It is curious that benzoic acid, when taken into the organism, is eliminated in the urine in the form of hippuric acid—a fact which was first made known by Mr. Ure.

It may be prepared by adding milk of lime to fresh cows' urine. The mixture is to be boiled for a few minutes, strained, and exactly neutralised with hydrochloric acid. The solution is next to be boiled down to one-eighth of its original bulk, and considerable excess of hydrochloric acid added, when brown crystals of the acid form. These may be purified by solution in water, through which a current of chlorine is to be transmitted, in order to decolorise the liquid. It may always be readily obtained from human urine after taking ten grains of benzoic acid.

The quantity of hippuric acid is increased when a purely vegetable diet is taken; but it is certain that the whole of the hippuric acid formed in the organism is not derived from this source. The proportion of hippuric acid in human urine was formerly considered to be so small, that it was scarcely possible to make a satisfactory quantitative determination; but Hallwachs has lately shown that as much as *thirty grains* or upwards are excreted in twenty-four hours. Weissmann obtained as much as 34·5 grains from his own urine in the course of twenty-four hours, when he was on a mixed diet.

Very little is known with reference to the formation of hippuric

acid; and although the subject has been very carefully investigated by Kühne and Hallwachs, who have published two very elaborate memoirs, there still remains much to be discovered. These observers hold that the hippuric acid is produced from the glycocol formed in the liver. Hallwachs is led to conclude, from numerous experiments, that the production of hippuric acid is determined rather by the chemical changes going on in the organism, than by any peculiarities of the food; for, if a purely animal diet was taken, hippuric acid was still found in the urine.* Lehmann found much hippuric acid in the urine of fever patients, and always detected it in diabetic urine.

Robin and Verdeil give drawings of some crystals which they found in the urine of a man aged 30, who took little exercise, but lived on highly nitrogenised diet: and which they considered to be hippuric acid: a statement apparently founded upon the resemblance of these crystals to those produced by the decomposition of hippurate of soda. They do not mention that the crystals were subjected to any chemical examination; and, in the absence of stronger evidence than mere resemblance in form, it seems to me that we are hardly justified in assuming that the crystals were composed of hippuric acid. It is very doubtful if this acid ever crystallises in urine spontaneously.

141. **Extractive Matters.**—Under the head of extractive matters are included certain organic substances which have never been obtained in a state of perfect purity, which are uncrystallisable—not volatile without decomposition—and incapable of being isolated. Chemists have described several kinds of extractive matters characterised by their behaviour with solutions of acetate of lead, bicloride of mercury, tincture of galls, &c. Within the last few years, however, several bodies, formerly included under the indefinite term of extractive matters, have been separated, and their chemical properties accurately determined. As instances, I need only mention albuminate of soda, binoxide and teroxide of protein, creatin and creatinine, hippuric acid, lactic acid and lactates, and certain colouring matters. The extractive matters in urine are entirely excrementitious; but it seems most probable that those present in the blood represent a certain stage of the metamorphosis of some of the constituents of

* An excellent review of these researches will be found in Vol. XIV., p. 156, of the "*Medico-Chirurgical Review.*"

that fluid—either a state intermediate between the nutritive pabulum and the tissue into which it is to be converted (progressive metamorphosis or histogenesis), or a condition resulting from the disintegration of tissue previous to its elimination from the body in the form of urea, creatine, uric acid, &c. (regressive metamorphosis or histolysis). The extractive matters of urine may be divided into three kinds.

142. **Water Extract.**—The first is called water extract, because it is insoluble in absolute alcohol, and in spirit of specific gravity ·833, but is soluble in water. It exists only in small quantity. Infusion of galls and bichloride of mercury produce scarcely any effect upon it, but neutral and basic acetates of lead give copious precipitates.

143. **Spirit Extract.**—The second kind of extractive matter is termed spirit extract, because it is insoluble in absolute alcohol, but soluble in water, and in spirit ·833. It contains much chloride of sodium. The solution of this extract is unaffected by infusion of galls, bichloride of mercury, and neutral acetate of lead; but a bulky precipitate is caused by basic acetate of lead.

144. **Alcohol Extract.**—The alcohol extract is soluble in water, in spirit ·833, and also in absolute alcohol. Its chemical reaction appears to be very similar to the last.

These are the extractive matters which are met with in healthy urine. In certain diseases, however, extractives drain off from the blood, and sometimes in very large quantity, which are not present in a state of health. My friend, Dr. G. O. Rees, many years since showed that this extractive could be detected in morbid urine by adding tincture of galls; and that the proportion varied greatly in different cases. Healthy urine is scarcely affected by tincture of galls, but this blood-extractive is at once precipitated by it. In order to detect it, tincture of galls is to be added to the filtered fluid; and if this extractive is present, a precipitate is *at once* produced. Should the urine contain albumen, this must, in the first instance, be separated by boiling and filtration. It is only the precipitate which *immediately* follows the addition of the tincture of galls that must be noticed. In some cases, the extractive drains away from the blood, without the escape of albumen. ("Lettsomian Lectures," by

G. O. Rees, M.D., F.R.S.; "*Medical Gazette*," 1851.) I shall have occasion to recur again to this interesting subject, when discussing the characters of the urine in disease.

One thousand grains of healthy urine will contain from fifteen to twenty grains of extractive matters. The solid matter contains from 15 to 40 per cent. of these substances. In twenty-four hours, about 200 grains of extractive matters are eliminated in the urine.

The physiological importance of extractive matters is quite unknown, and hitherto no one has been able to ascertain their nature, or discover the part which they play in the animal economy. Their presence in the blood, and in all the animal fluids, as well as in the solid organs and in the excretions, clearly prove them to be substances of great importance; and it must be remembered that, in the urine, the proportion of extractive matter is often greater than that of the urea itself. The amount of extractive matters in the different fluids and secretions of the body is a subject well worthy of investigation, and likely to yield valuable results.

145. **Sulphur Compounds.**—In certain cases of disease, urine, soon after it is passed, evolves a very powerful odour of sulphuretted hydrogen, probably resulting from the decomposition of substances rich in sulphur. This fact has been observed by many, and I noticed frequently, in examining the urine of insane patients, a piece of paper, anointed with a solution of acetate of lead, soon became blackened from the formation of sulphuret. Considerable quantities of unoxidised sulphur have been obtained even from healthy urine. Ronalds, in five different cases, obtained from 3 to 5 grains of sulphur in the twenty-four hours ("*Philosophical Transactions*," 1847), and Griffiths found 4 grains in healthy urine. These observations are confirmed by Dr. Parkes, and Bischoff and Voit have stated that a large quantity of sulphur is constantly present in the urine of dogs.

146. **Sugar.**—Brücke has lately again stated that traces of sugar always exist in healthy urine, and his observations have been confirmed by Dr. Bence Jones. ("*Trans. Chem. Soc.*," April, 1861.) This subject will come under notice in a subsequent chapter.

147. **Vesical Mucus.**—Vesical mucus exists in very small quantity in healthy urine. It forms a faint flocculent cloud, which settles

towards the lower part of the fluid, after the specimen has been allowed to stand for some time (§ 114).

148. Lactic Acid ($2\ HO_1C_{12}H_{10}O_{10}$).—Lactic acid is not constantly present in healthy urine in quantities sufficient to be recognised; but sometimes it is found in the urine of persons who may be considered to be in tolerably good health. Liebig denied its existence in healthy urine altogether; but its presence in this fluid—at least, under certain physiological conditions, as stated many years ago by Berzelius—has been confirmed by Franz Simon, Lehmann, and others; although, on the other hand, it appears nearly certain that the salt assumed to be lactate of zinc by many observers was not really of this nature, but probably consisted of a combination of another acid, which, unlike lactic acid, contains nitrogen.

In order to ascertain the presence of lactic acid, a baryta salt should be first prepared, as Lehmann has recommended, from which a lime salt is easily formed by the addition of sulphate of lime. The lactate of lime crystallises in double brushes, as seen by the microscope. From the lime salt a copper salt is prepared by the addition of sulphate of copper. ("*The Microscope, in its Application to Clinical Medicine*," 2nd Edition, Figs. 123, 124, p. 123.) This is examined by the microscope. The lactate of copper is decomposed by placing a small bar of zinc in the solution; and upon this, in a short time, crystals of lactate of zinc are deposited, whose angles may be measured in the microscope. ("*The Microscope*," &c., 2nd Edition, Fig. 125, p. 123.) For the details of this process, I must refer to Lehmann's "*Physiological Chemistry*," translated by Day, Vol. I., p. 91.

According to some observers, the phosphate of lime and the ammoniaco-magnesian phosphate are held in solution by the lactic acid. They may also be dissolved by the chloride of ammonium, according to Dr. G. O. Rees. MM. Cass and Henry have endeavoured to prove that the lactic acid exists in the form of lactate of urea. Lactates of soda and ammonia are also most probably present in the majority of cases. Lactic acid is occasionally met with in urine, and some other organic acids which are sometimes present are described below.

149. Oxalic Acid ($HO_1C_2O_3$) has been found in healthy urine

by Strahl and Lieberkühn. Böeker estimated the quantity at 1·42 grains in twenty-four hours.

150. Peculiar Organic Acids.—Besides carbonic acid, urine contains, according to the observations of Städeler, a peculiar acid to which the name of *damaluric acid* has been given. It has a powerful odour; but little is yet known of the circumstances under which this volatile acid occurs. *Phenylic* or *carbolic acid*, usually known as *creasote*, has also been detected in urine; but these acids, with the *damolic* and *taurylic acids*, as they occur in urine, have as yet been so little studied, that we know nothing of any practical importance connected with them. Campbell and Lehmann state that urine contains traces of formic acid ($C_2 H_2 O_4$).

Although the urea and some other constituents of the urine may be more conveniently and more quickly estimated, by the volumetric process of analysis (Chapter II.), the practitioner is recommended to carry out the following routine plan of analysis. In the course of the examination he will become practically familiar with the chemical and microscopical characters of the most important constituents of the urine. Small quantities of the residues, &c., obtained, should always be submitted to microscopical examination.

Systematic Qualitative or Quantitative Analysis of Healthy Urine.

151. Organic Constituents.—1. In the first place, the reaction and specific gravity of the specimen are to be taken, and any general points noticed. (Lecture I.)

2. Two portions of urine (500 or 1,000 grains) are to be placed in separate porcelain capsules, and evaporated to dryness with the cautions previously given. In the first portion, A, the *organic constituents* are to be estimated; in the second, B, the proportion of *salts* is to be ascertained (Chapter VII., § 183). A, when dry, is to be weighed; and thus the quantity of *water* is obtained. The residue is known to be quite dry when *two successive* weighings exactly correspond. The solid matter is to be treated with successive portions of boiling alcohol, until nothing more is taken up. These are decanted into another basin, or passed through a filter; and the alcoholic solution, containing urea and extractives, is to be evaporated

nearly to dryness—alcohol extract—C; the residue insoluble in alcohol—D.

C. The alcohol extract is to be treated with a few drops of water, and placed over the water-bath. Crystals of oxalic acid are to be added until they are no longer dissolved. It is important to add *excess* of oxalic acid crystals. A drop of the solution may be placed on a glass slide, and the crystals of oxalate which form subjected to microscopical examination (§ 128, Plate XI., Fig 56). The mixture is allowed to cool, and the impure crystals of oxalate of urea and excess of oxalic acid are to be slightly washed with ice-cold water, and pressed between folds of bibulous paper, to absorb the extractive matters. The crystals are to be redissolved in a small quantity of water, placed in a large vessel, and carbonate of lime added until effervescence has entirely ceased. After the mixture has been allowed to stand for some time, it is to be thrown upon a filter.

The solution separated from the oxalate of lime consists of *urea* with a little colouring matter. It is to be carefully evaporated to dryness, and weighed. If the residue is not entirely soluble in alcohol, it contains impurity which must be deducted from the weight of the urea.

Or, the alcohol extract, C, may be treated with a few drops of water, so as to form a thick syrup; and nitric acid added by drops, while the basin which contains the extract is plunged in a freezing mixture. A little of the mixture should be examined in the microscope (Plate XI., Fig. 55). When sufficient nitric acid has been added to combine with all the urea present, the whole is to be allowed to stand for some time; the crystals carefully washed with a very little ice-cold water, and carefully placed on a porous tile, which will absorb the excess of nitric acid and the extractive matters, leaving crystals of *nitrate of urea*, which are to be carefully dried and weighed. By a simple calculation, the quantity of urea is easily ascertained.

D. The residue insoluble in alcohol is to be treated with boiling water and thrown upon a filter. There remain upon the filter, *mucus* from the bladder and other parts of the urinary mucous membrane; *uric acid; phosphate of lime;* and *ammoniaco-magnesian phosphate*, with a mere trace of *silica*. This residue is to be carefully dried and weighed. It is then to be incinerated; and, after the ash has been completely decarbonised, its weight is to be

deducted from that of the residue insoluble in alcohol; and thus the proportion of uric acid and vesical mucus is ascertained. By deducting the united weight of all these different substances—urea, uric acid, mucus, and earthy phosphate—from the solid matter, we calculate the quantity of extractive matter present. According to this plan, we have ascertained the proportion of the following constituents in 500 or 1,000 grains of urine.

Water	....
Solid Matter	....
Urea	....
Extractive matters	....
Mucus and uric acid	....
Earthy phosphate and silica	....
Fixed salts	....

Many of the processes above described are imperfect, and likely to give results which are not quite accurate; still the plan is one which is practically useful, and, when a series of results is required, answers very well. In the analysis of animal fluids, it is impossible to attain to perfect accuracy, owing to the changes taking place in the ingredients of the fluid, which are produced by the analytical processes to which they are subjected. Moreover, in such inquiries, it is far more desirable to know the general change which takes place, under various circumstances, in the quantities of the different constituents, than to be acquainted with the exact absolute proportion of each present.

CHAPTER VII.

HEALTHY URINE. III. INORGANIC CONSTITUENTS.—*On the Salts generally—Changes effected in the Composition of the Salts by Incineration—Proportion of the Saline Matter in Urine — Phosphates — Common Phosphate of Soda — Alkaline Phosphate of Soda—Acid Phosphate of Soda—Phosphate of Soda and Ammonia—Phosphate of Magnesia—Phosphate of Ammonia and Magnesia—Phosphate of Lime—Estimation of the Alkaline and Earthy Phosphates—Quantity of Phosphates—Sulphates; Quantity; Estimation—Carbonates—Chloride of Sodium; Quantity; Detection—Circumstances affecting the Excretion of Chloride of Sodium—Bases in Urine—Soda and Potash—Lime—Magnesia—Iron—Silica—Alumina—Systematic Quantitative and Qualitative Examination of the Saline Matter of Healthy Urine.*

INORGANIC CONSTITUENTS OF HEALTHY URINE.

THE saline or inorganic constituents of healthy urine are composed of those substances which remain after the solid matter has been exposed to a red heat, and the carbon burnt off so as to leave a pure white ash. If a little of the solid matter of urine or other animal fluid be placed in a platinum capsule, or upon a piece of platinum foil, which should be very large in proportion to the quantity of solid matter operated on, and exposed to the red heat of a spirit or gas lamp, it will melt and boil up, giving rise to the evolution of offensive gases, which result from the decomposition of the organic constituents. When this has ceased, a charred mass, consisting of carbon and the saline matters indestructible at a red heat, of the urine, remains. After this black spongy mass has been kept in the open capsule, at a dull red heat, for a few hours, the carbon will

gradually disappear, in consequence of the action of the oxygen of the air, which at this temperature combines with it, and forms carbonic acid. A pure white ash, which has an alkaline reaction alone remains; and this consists entirely of saline or inorganic material, which is indestructible at a red heat.

152. Changes effected in the Composition of the Salts by Incineration.—Now, it must not be concluded that the salts which we find in the ash existed in precisely the same state in the urine previous to incineration; for we know that many of these salts, when heated together, undergo mutual decomposition. Some of them may even be volatilised, if kept for a considerable time at a red heat. A mixture of carbonate of soda and chloride of ammonium becomes decomposed at a red heat. Chloride of sodium remains behind, while carbonate of ammonia is evolved. Any lactates, oxalates, and salts, of other organic acids present in the urine, will be found in the ash, in the form of carbonate, although no carbonate existed in the urine originally. The ammoniaco-magnesian or triple phosphate will be found in the ash as phosphate of magnesia; the phosphate of soda and ammonia, as phosphate of soda. Other phosphates also become completely changed by the process of incineration, and by the action of other salts present in the ash upon them. During the incineration, a considerable loss of chlorine also takes place.

Again, unoxidised substances, such as sulphur and phosphorus, and partially oxidised compounds, in combination with organic materials, will become oxidised in the process of decarbonisation; and will, therefore, be found in the ash in the form of sulphuric and phosphoric acid. These will react upon some of the bases present, and sulphates and phosphates will be formed.

Professor Rose, of Berlin, in a beautiful series of experiments, has proved that the mineral constituents exist in very different states in various organic substances. From the *carbonaceous* ash of some organic matters, the greater proportion of the salts can be extracted with water or acids; while, in other cases, but little saline matter can be separated, unless the mass be exposed to the oxidising action of the air for some time. This shows that the substances must have originally existed in an unoxidised or in a partially oxidised state, probably in combination with some organic material.

In certain substances, then, the greater quantity of the mineral material is perfectly oxidised (*teleoxidic*); in others, it exists partly in an oxidised and partly in an unoxidised state (*meroxidic*). Professor Rose was not able to discover any substance in which it occurred completely unoxidised (*anoxidic*). In blood, milk, yolk of egg, and flesh, a considerable portion of the mineral constituents are *meroxidic;* while, in urine and bile, they are almost entirely *teleoxidic:* which is exactly what we should expect, when we consider the different nature and offices of these fluids.

153. **Proportion of Saline Matter in Urine.**—About one-fourth of the solid matter of healthy urine consists of saline constituents which are not destroyed by a red heat.

One thousand grains of healthy urine, containing from forty to sixty grains of solid matter, will give from ten to fifteen grains of fixed salts. Of the salts, more than nine-tenths are soluble in water (alkaline salts); while the remainder can only be obtained in solution by adding an acid (earthy salts). A mere trace remains behind, which is insoluble in water, acids, and alkalies. This consists of silica, with, perhaps, a little carbon which has resisted oxidation. These numbers are, of course, only approximative, as the amount of salts is liable to great variation.

The saline constituents soluble in water are composed of the following acids and bases:—

Sulphuric acid (and sulphur).	Potash (and potassium).
Phosphoric Acid.	Soda (and sodium).
Hydrochloric acid (chlorine).	

The salts may be readily obtained in a crystalline state by dissolving the residue in hot water, and evaporating a few drops of the solution on a glass slide. The crystals are represented in the "*Illustrations of Urine*," Plate I., Fig. 2.

The mineral constituents insoluble in water are composed of the following acids and bases:—

Phosphoric acid.	Lime.
Carbonic acid (occasionally).	Magnesia.
Silicic acid or silica.	Alumina (sometimes).

In disease, the mineral constituents have been found to vary in quantity quite as much as the organic substances; and other salts are not unfrequently found, which will come under notice at a future

time: while occasionally one or more of the saline compounds mentioned in the above list are altogether absent.

The organic constituents of the urine have hitherto received a greater share of attention than has been given to the inorganic salts; but, from recent investigations, it seems probable that, before long, the physician will regard a departure from the healthy standard in the saline constituents, with as much attention as he has been accustomed to observe an increase or diminution in the quantity of the urea, uric acid, or other organic ingredients.

154. **Phosphates.**—The phosphates are a very important class of salts, which exist in greater or less quantity in all the tissues of the body, in the secretions, and in considerable proportion in the blood. The salts of phosphoric acid which are carried off from the organism in the urine, may be divided into two classes.

1. The *alkaline phosphates* are *soluble* in water, and are not precipitated from their solutions by ammonia or other alkalies. When ammonia is added to healthy urine, the *alkaline* phosphates are not thrown down. Some of the most important alkaline phosphates are *phosphate of soda*, *acid phosphate of soda*, and *phosphate of soda and ammonia.*

2. The earthy phosphates are *insoluble* in water, but are dissolved by the mineral acids. Most are soluble in organic acids, although they dissolve very slowly if the acids are dilute. They are held in solution even by carbonic acid. Most albuminous substances have the power of dissolving earthy phosphates; and casein holds in solution a considerable quantity of phosphate of lime. The earthy phosphates, as phosphate of lime and phosphate of magnesia, are always precipitated when ammonia is added to healthy urine.

Of the phosphoric acid eliminated in the urine in the form of phosphates, the greater proportion is doubtless taken in the food; but a certain amount is formed in the organism by the oxidation of the phosphorus of albuminous tissues, which takes place during their disintegration. Much of the phosphoric acid formed in the organism is doubtless produced in the nervous tissue.

Phosphoric acid is one of those acids which exist in three forms —the monobasic, bibasic, and tribasic acids, which combine respectively with one, two, or three equivalents of base, to form three different classes of salts.

Tribasic phosphates . . .	3 Na O, PO^5+24 Aq. 2 Na O, HO, PO^5+24 Aq. Na O, 2 HO, PO^5+2 Aq. Na O, HO, NH^4 O, PO^5+8 Aq.
Bibasic or pyrophosphates .	2 Na O, PO^5+10 Aq.
Monobasic or metaphosphates	Na O, PO^5.

Now, the phosphates found in the organism are all *tribasic phosphates*, and consist of three equivalents of base, combined with one equivalent of phosphoric acid, with different proportions of water of crystallisation. The elements of the base of a tribasic phosphate may be various. Thus they may consist of three equivalents of soda or other base, or two equivalents of soda and one of water acting the part of a base, or one equivalent of soda and one of ammonia and one of water acting the part of a base, combined with one equivalent of phosphoric acid.

The chemical composition of the phosphates occurring in urine is represented in the following table:—

Common or rhombic phosphate of soda, having an alkaline reaction .	2 Na O, HO, PO^5+24 Aq.
Acid phosphate of soda, having an acid reaction	2 HO, Na O, PO^5+2 Aq.
Alkaline phosphate of soda, having a highly alkaline reaction . .	3 Na O, PO^5+24 Aq.
Phosphate of potash*	3 KO, PO^5.
Phosphate of ammonia and magnesia, ammoniaco-magnesian or triple phosphate	2 Mg O, NH^4O, PO^5+12 Aq.
Acid phosphate of lime . . .	2 Ca O, HO, PO^5+3 Aq.
Phosphate of lime (bone-phosphate)	3 Ca O, PO^5.

Alkaline Phosphates.

155. Common Phosphate of Soda (2 Na O, HO, PO^5+24 Aq).—This salt exists in healthy urine in the proportion of about two grains in one thousand. The fixed salts contain perhaps from 20 to 30 per cent. of ordinary phosphate of soda. Its presence in healthy urine may be proved by adding absolute alcohol to the syrupy fluid

* It is doubtful if phosphate of potash usually exists in urine, as chloride of sodium and phosphate of potash decompose each other, forming chloride of potassium and phosphate of soda. It is not improbable that it may exist in urine in which the chloride of sodium is present in very small quantity, or altogether absent, as in pneumonia and some other acute diseases.

obtained by evaporating the urine over a water bath. This concentrated fluid is poured off from the salts which have crystallised, and placed in a small glass vessel. The alcohol is added; and, after the mixture has stood for some time, the crystals are deposited upon the sides of the glass. This method is given by Robin and Verdeil. ("*Traité de Chimie Anat. et Physiol.*," par Ch. Robin et F. Verdeil.)

156. Acid Phosphate of Soda ($Na\ O,\ 2\ HO,\ PO^5 + 12\ Aq$).—This salt has only been found in the urine; and to it, at least in many cases, the acid reaction of the urine is due. This acid phosphate of soda may be formed from the common phosphate (which has an alkaline reaction), by the addition of uric acid, which removes from the common phosphate one equivalent of soda, forming *urate of soda*; and the reaction of the mixture becomes acid, in consequence of the formation of the *acid phosphate.*

The acid phosphate of soda may be obtained from the concentrated urine treated with absolute alcohol, after the separation of the common phosphate. The acid salt, which is much more soluble, becomes deposited in the course of a few days; but its separation may be expedited by the addition of ether. The phosphate has been separated from the urine by MM. Robin and Verdeil, who attribute the acid reaction of urine to its presence ("*Comptes Rendus. Mém. de la Soc. de Biologie*," Paris, 1850, p. 25; also "*Traité de Chimie Anat. et Physiol.*," 1853). The crystals of this salt are figured in Robin and Verdeil's "*Atlas*," Plate IX., Fig. 2.

157. Alkaline or Basic Phosphate of Soda.—$3\ Na\ O,\ PO^5 + 24\ Aq$. —This phosphate is considered by some to be present in urine; but it is so readily altered by other salts present, that it is impossible to obtain it from the animal fluids in a state of purity. In the presence of carbonic acid, it is decomposed: one equivalent of soda unites with the carbonic acid to form carbonate of soda, and common phosphate of soda is formed, both which salts have an alkaline reaction—$3\ Na,\ O,\ PO^5 + CO^2 + HO = 2\ Na\ O,\ HO,\ PO^5 + Na\ O,\ CO^2$.

Liebig has shown that it is not present in healthy urine, as was stated by Heller; and Messrs. Robin and Verdeil do not enumerate this phosphate as one of the constituents of urine: indeed, if this phosphate were formed, it would, in all probability, be at once resolved into salts of a more stable nature.

158. Phosphate of Soda and Ammonia ($Na\ O$, NH^4O, HO, PO^5, $+ 8\ Aq.$)—This salt, although probably not present in perfectly fresh urine, is usually enumerated as one of the phosphates found in the secretion. The crystals of phosphate of soda and ammonia, or microcosmic salt, are beautiful transparent four-sided prisms.

159. Phosphate of Potash ($3\ KO$, PO^5) is probably not present in healthy human urine; but it has been detected by Bossingault in the urine of the pig, in the proportion of 1·02 per 1,000.

Many vegetable tissues contain a large quantity of phosphate of potash; and it is met with in the juice of muscle in considerable quantity.

160. Quantity.—The proportion of alkaline phosphates in the organism varies very greatly according to the nature of the food, amount of exercise, &c. Generally, the proportion is smaller in herbivorous than in carnivorous animals. Muscular fibre contains a large amount of phosphates. Wheat, and the seeds of the cerealia generally, contain a considerable quantity of alkaline phosphates. Robin and Verdeil found, in the ash of the blood of a dog fed upon flesh, as much as 12 per cent. of phosphoric acid, combined with soda and potash; while the ash of the blood of the ox did not contain more than 3 per cent. When the dog was fed upon potatoes, the proportion fell to 9 per cent. The ash of the blood of man contained about 10 per cent. of phosphoric acid. In urine, Berzelius found 2·94 per 1,000; and Simon, from 1·25 in slightly acid urine, to 2·75 in very acid urine.

Breed and Winter estimate the quantity of phosphoric acid removed from the organism in the urine, in the course of twenty-four hours, at from 59·48 to 79·97 grains. The proportion increased considerably after taking food. This quantity corresponds to from 120 to 160 grains of phosphatic salts. Dr. Parkes estimates the phosphoric acid at 48·80 grains in 24 hours.

The quantity of phosphoric acid increases for some hours after a meal. Vogel, Winter, and others have made numerous experiments on this point; and their researches show that the hourly variation in the excretion of phosphate is regular. The morning urine contains the smallest quantity. In some of Dr. Bence Jones's analyses, however, the quantity of alkaline phosphates is even greater in the urine passed before than in that secreted after a meal. ("*Animal Chemistry*," p. 81.)

The proportion of phosphates in the urine depends much upon the nature of the food. The quantity is increased if phosphorus be taken, proving that this substance does become oxidised in the organism. That the greater proportion of the alkaline phosphates present in the urine are derived from the food is rendered evident by referring to the amount introduced into the organism in this manner. A man taking about fourteen ounces of bread and twelve ounces of meat, with half a pound of potatoes and half a pint of milk, would take about 130 grains of alkaline phosphates.* As we have seen, he would eliminate, in his urine, about the same quantity. These numbers are only to be regarded as rough approximations to the truth; but I think, at present, it must be admitted that the quantity of phosphate excreted in the urine, and formed in the organism, is so small in comparison to that derived from the food, of which the amount is liable to great variation, that, in the present state of animal chemistry, it is quite impossible to form an estimate of the amount derived from the former source, or to separate this from the phosphates taken in the ingesta.

Still it is certain that some of the phosphoric acid is formed within the organism, by the oxidation of the phosphorus of the albuminous tissues; but this must bear but a small proportion to the whole amount of phosphate removed in the urine, as the above data conclusively show.

The fluid which surrounds the elementary fibres of muscle has an acid reaction, depending probably upon the presence of acid phosphate of soda, produced by the action of lactic or some other organic acid upon phosphate of soda. Du Bois Raymond has, however, shown that this acid reaction is not met with when the muscles are at rest. Recent experiments have shown that the amount of disintegration taking place in muscular tissue during its activity is much less than was supposed. It is probable that very much of the material generally ascribed to the disintegration of the muscle is really due to the chemical changes produced in the nerves ramifying on the surface of the elementary fibres. The ashes of most tissues contain phosphates

* 14 oz. of bread	contain	53·2	grs. of phosphates.	
12 oz. of beef	,,	40·7	,,	,,
½ lb. of potatoes	,,	11·0	,,	,,
½ pint of milk	,,	32·0	,,	,,
		136·9	grs. of mixed phosphates.	

in large proportion; and Schmidt has shown that a considerable quantity of phosphate is always present in young tissues. The quantity of alkaline phosphate required by the organism is considerable; for, besides the large proportion which is excreted in the urine, the ash of the solid excrements contains as much as 20 per cent. alone. The phosphoric acid required is, no doubt, supplied principally by the food, partly in the form of phosphatic salts, partly as phosphorus which is oxidised in the organism. We shall recur to this subject when we have to consider the elimination of the phosphates in disease.

Earthy Phosphates.

The earthy phosphates met with in the urine are—1, the *ammoniaco-magnesian phosphate*, also termed *triple phosphate*, or *phosphate of ammonia and magnesia;* 2, *Basic phosphate of ammonia and magnesia;* 3, *Phosphate of Magnesia.*

These earthy phosphates occur in very small quantity in urine. The secretion in health contains not more than from 1 to 1·5 part in 1,000, and the solid matter contains from 1·5 to 2 per cent. The quantity present in different cases undergoes but slight variation, and seems to be determined, to a great extent, independently of the chemical changes going on in the body. Most of the solids and fluids of the organism contain small quantities of the earthy phosphates. The amount depends, in great measure, upon the quantity of alkaline earths present. Ktetzinsky has shown that in urine there are two parts of phosphate of lime to one part of phosphate of magnesia.

In healthy urine, these earthy phosphates are held in solution, in all probability, by the free acid of the urine, and in some measure by the acid phosphate of soda. The chloride of ammonium present may also contribute to maintain the earthy phosphates in solution in the urine (Dr. G. O. Rees). Very slight changes are sufficient to cause the precipitation of the ammoniaco-magnesian phosphate; and beautiful crystals of this salt are sometimes formed in urine which has a decidedly acid reaction.

It is important to distinguish between *excess* of phosphates in the urine and a *deposit* of earthy phosphate; for a large quantity of earthy phosphate in the urine may pass unnoticed by the practitioner, because it is in a state of *solution;* while a smaller quantity in an *insoluble* state, and therefore very conspicuous, is likely to

receive from him a larger share of attention than its slight importance demands.

161. **Precipitation of Earthy Phosphates by Heat.**—It is very important to bear in mind that the earthy phosphates are precipitated from some specimens of urine by heat. This precipitate closely resembles that which is produced, in many specimens of albuminous urine, upon the application of heat. It is, however, at once distinguished from albumen by the addition of a few drops of nitric acid, which instantly dissolves the phosphate, while albumen is unaffected by it. Such a mistake has many times been made; and I need hardly say how important it is to avoid the possibility of such an error, as it may lead the practitioner to form an unfavourable prognosis in a case in which there is really no cause whatever for anxiety. The cause of this occasional precipitation of earthy phosphate is obscure. By Dr. Rees it is attributed to an excess of the phosphates being held in solution by chloride of ammonium. Dr. Brett considers that in these cases it is dissolved by carbonic acid; while Dr. Bence Jones attributes this precipitation to the excess of free acid of the urine being neutralised by an alkali, or by common phosphate of soda.

162. **Phosphate of Lime ($3\ CaO,\ PO^5$)** exists in healthy urine dissolved in acids, in certain salts, or in organic matters. Phosphate of lime is soluble in a solution of carbonic acid, in bicarbonates, and in chloride of ammonium. Albumen and fibrine always retain a certain quantity, and casein holds a large amount in solution. It is found in almost all the tissues, and, when separated, usually occurs in an amorphous state. In urine it sometimes crystallises. The ash of urine contains between 2 and 3 per cent. of this phosphate, and that of excrements upwards of 12 per cent. It may be obtained in quantity from bones.

163. **Acid Phosphate of Lime ($2\ CaO,\ HO,\ PO^5 + 3\ HO$.**—The existence of this phosphate in urine constantly, is questionable; but, as before remarked, the composition of the phosphates is constantly altering; and an acid phosphate of lime is readily formed by the action of an organic acid on the neutral phosphate of lime.

164. **Phosphate of Ammonia and Magnesia, Triple, or**

Ammoniaco-Magnesian, Phosphate ($NH^4 O, 2 Mg O, PO^5 + 12 HO$).—The presence of this salt, which is frequently met with in the animal fluids, usually depends upon decomposition having commenced, in which case the ammonia set free combines with the phosphate of magnesia to form the triple phosphate. At the same time there can be no doubt that crystals of triple phosphate are sometimes found in acid urine—not merely forming a pellicle which alone is alkaline, while the fluid beneath retains its acidity (Thudichum)—but as a distinct deposit, leaving a clear supernatant fluid. Lehmann and other observers doubt the correctness of this observation; but the fact has been observed in this country several times, and I have noticed it myself more than once or twice. It is quite possible that the acid reaction may depend upon chloride of ammonium, or some other salt which reddens litmus, and not upon the existence of free acid.

Crystals of triple phosphate are slightly soluble in pure water, but are rendered quite insoluble by a trace of ammonia and ammoniacal salts. They give beautiful colours when examined with a ray of polarised light.

165. **Phosphate of Magnesia ($3 Mg O, PO^5 + 7$ Aq.)** —This phosphate is found in considerable quantity in the urine of certain herbivorous animals, and it appears to be a constituent of certain urinary calculi. It is doubtful if it is often present in human urine; but Robin and Verdeil have discovered it in several organs, and also in morbid products. In animal fluids generally, the phosphate of magnesia combines with ammonia, forming the salt which has just been described. When discussing the deposits of phosphates, I shall have to revert to this subject.

166. **Microscopical Characters of the Earthy Phosphates.**—The phosphate of lime is usually deposited from urine in an amorphous form. Under the microscope, even when the highest powers are employed, the deposit when first formed is found to consist of minute granules. ("*Illustrations*," Plate XXI., Fig. 4.) Occasionally it occurs as round or oval particles of a high refractive power. Sometimes two of these small particles are connected together, and produce a crystal of the dumb-bell form. They vary much in size, but are usually very small.

After some time has elapsed, the amorphous granular deposit of phosphate of lime assumes a crystalline form. Dr. Hassall has found

that the crystals formerly regarded as a rare form of triple phosphate are really composed of phosphate of lime. Dr. Bence Jones has also obtained crystals of phosphate of lime from urine by adding chloride of calcium, and Dr. Roberts has written a paper on the same subject. I have found that beautiful crystals of phosphate of lime can always be obtained by allowing solutions of phosphate of soda and chloride of calcium in glycerine gradually to mix together. In this manner very perfect crystals may be produced. Many days may elapse before large crystals are found.

The *phosphates of magnesia* crystallise in several different forms, which seem to be determined by slight changes in circumstances. The first is the stellate form, which occurs when ammonia is added to healthy human urine. The crystal consists of from four to five feathery rays, with a minute oval mass situated at the origin of each ray from the centre. These crystals gradually assume the more common form of the triple phosphate: secondly, that of a beautiful triangular prism, with obliquely truncated extremities. Great variation, however, is observed in the form of these crystals; sometimes they appear almost square; and frequently they might be mistaken for octohedra, in consequence of the approximation of the obliquely truncated ends, and the shortening of the intermediate portion of the crystal. Prisms or knife-rest crystals of triple phosphate are represented in Plate XII., Fig. 62. The feathery crystals of triple phosphate are represented in the "*Illustrations*," Plate IX., Fig. 2. After standing for some time, the rays alter in shape, and gradually little triangular crystals begin to make their appearance, as represented at *a*. After the lapse of some days, they are entirely converted into the ordinary triangular crystals. ("*Illustrations*," Plate IX., Fig. 1.; Plate XXI., Figs. 1, 3; Plate XXIII., Fig. 1). Other forms of triple phosphate are described in the chapter on *urinary deposits*.

167. Estimation of the Earthy and Alkaline Phosphates.— The earthy phosphates (*phosphate of lime* and *phosphate of magnesia*) are easily detected by ammonia. If a few drops of solution of ammonia are added to a specimen of healthy urine, a turbidity is soon observed, owing to the precipitation of phosphate of lime in an amorphous form, and triple or ammoniaco-magnesian phosphate in flocculent snow-like crystals, which increase in size for some time

after their first precipitation. Stirring favours the separation of the phosphates; but the form of the crystals must, of course, be studied in a mixture which has been allowed to remain quiet. If it is required to estimate the proportion of these earthy phosphates, it is only necessary to separate them by filtration, ignite in a platinum capsule, and weigh the ash.

168. **Alkaline Phosphates.**—The phosphoric acid combined with the alkalies may be precipitated from the fluid filtered from the earthy phosphates by the addition of a salt of lime or magnesia, when an insoluble deposit, composed of phosphate of lime or phosphate of ammonia and magnesia, is produced. If it is desired to ascertain the quantity of alkaline phosphates, it is only necessary to filter the precipitate, dry, ignite, and weigh it. From the phosphate of lime or phosphate of magnesia it is easy to calculate the proportion of phosphoric acid present; but, for ordinary purposes, it is enough to consider the weight as corresponding to the quantity of alkaline phosphates present in the urine, there being but slight difference in the equivalent numbers of the salts. The volumetric method of estimation, in which the phosphate is precipitated by a persalt of iron, has been described in Chapter II. Nitrate of silver produces in urine a yellow precipitate of tribasic phosphate of silver, which is soluble both in excess of ammonia and also in nitric acid. Upon adding a few drops of the former to the yellow deposit in this test-tube, it instantly dissolves. If nitric acid just sufficient to neutralise the ammonia present be added, the yellow precipitate reappears; but, when one drop more falls in, it is immediately redissolved. This might be repeated many times. The precipitate of *chloride* of silver is quite *insoluble* in nitric acid, although soluble in ammonia; so that, in testing for chloride of sodium in urine, it is always important to add a few drops of nitric acid, to prevent the precipitation of the phosphate of silver.

169. **Sulphates.**—Unlike the phosphates, the sulphates are present in very small quantities in the fluids of the body generally. The urine, however, contains a large quantity. This class of salts is not present in the milk, bile, or gastric juice. The blood contains only ·20 per 1,000; while, in healthy urine, sulphates exist in the proportion of from 3 to 7 parts per 1,000.

The proportion of sulphates undergoes a considerable increase

after violent exercise, and under the influence of a purely animal diet—conditions under which the urea suffers a considerable augmentation. In fact, in all those conditions which are associated with an increased formation of urea, a large proportion of sulphates will also be observed. It would appear that the oxygen, hydrogen, carbon, and nitrogen of the albuminous substances, are eliminated in the form of urea; while the sulphur is removed in the state of sulphuric acid.

Dr. Bence Jones's experiments have shown that both vegetable and animal food increase the proportion of sulphates in the urine. When sulphuric acid, sulphur, or sulphates, are taken internally, the amount of these salts is augmented. These facts prove that the sulphates found in the urine are in great part formed during the disintegration of tissues. They must be regarded as excrementitious, and are probably not concerned in nutrition.

The sulphuric acid eliminated in the urine occurs in the form of sulphate of potash and soda.

The urine contains about 3·5 grains per 1,000 of sulphate of potash, and about 3·0 grains of sulphate of soda. About thirty grains of sulphuric acid, corresponding to about fifty-seven grains of the mixed sulphates, are excreted by a healthy man in twenty-four hours.

The sulphates present in the urine are all soluble, like the alkaline phosphates; and, in order to prove their presence in a fluid, it is necessary to add some salt, the base of which forms an insoluble precipitate with sulphuric acid. Baryta salts are the most convenient for this purpose. Either the nitrate of baryta or the chloride of barium may be employed. In testing for sulphates in urine, it is necessary to add a little free nitric or hydrochloric acid previous to the addition of the baryta salt, in order to prevent the precipitation of a *phosphate* as well as a *sulphate* of baryta. The former is very soluble in free acid; the latter quite insoluble. If the quantity of sulphate is to be estimated, it is necessary to boil the mixture, or to drop the baryta salt into the boiling solution; otherwise the pre-precipitated sulphate of baryta will pass through the pores of the filter. The phosphoric acid may be estimated in the clear fluid which passes through the filter by the addition of ammonia, which throws down phosphate of baryta. The contact of the air must, in this case, be avoided.

170. Sulphate of Lime has not been detected in human urine, but it has been found in that of animals, and is a constituent of some urinary calculi. I have seen crystals of sulphate of lime in the uriniferous tubes; and it is probable that it may be present in the urine, in some cases, in appreciable quantity. Traces of sulphate of lime are found in the blood. It is found in the pancreatic juice which has been kept for a few hours in a warm place, so that decomposition of some of the organic materials may take place.

171. Carbonates.—Carbonate of soda is not usually reckoned as a constituent of healthy urine, as its presence is entirely dependent upon the kind of food which the person has taken. For instance, carbonate of soda will often be found in the urine after large quantities of fruit have been eaten, in consequence of the salts of the vegetable acids becoming converted into carbonates during their passage through the organism. In the urine of herbivorous animals, alkaline carbonates are found; and frequently the carbonate of lime is also present. In the urine of rodents, these salts, particularly the latter, are abundant. Moreover, carbonate of soda may actually have been present in the urine, although it cannot be detected in the ash; for, if common phosphate of soda be heated with carbonate of soda, the carbonic acid is expelled, and the tribasic phosphate of soda remains. Hence the absence of carbonate from the ash of urine is not always a positive proof that the fluid did not contain lactates before it was subjected to chemical operations. On the other hand, a carbonate may be detected in the ash, although none was present in the urine, in consequence of the decomposition of oxalates and lactates during incineration.

172. Testing for Carbonate.—The presence of carbonic acid is very easily recognised, by the effervescence set up, immediately a little dilute acid is added to the ash. The best plan to test for carbonate in the ash is the following. A small portion of the dry ash is placed on a glass slide, and covered lightly with an ordinary square of thin glass. A drop of acid is then allowed to fall on the glass, so that it will gradually pass between the glasses by capillary attraction, and come into contact with the salt. If any bubbles of gas escape in consequence of the action of the acid, they will be confined beneath the thin glass, and one cannot fail to see them. If they be very

small, the specimens may be subjected to microscopical examination. In this manner, the slightest trace of carbonic acid can hardly escape notice.

If the quantity of carbonate is to be estimated, the ash must be placed in a little apparatus, from which the gas is conducted by a tube into another vessel containing lime or baryta water; or it may be caused to pass through the potash apparatus used in organic analysis. From the weight of the carbonate, that of the carbonic acid is easily calculated. In the last case, its weight is obtained directly.

173. **Chloride of Sodium** ($NaCl$).—Common salt is always present in healthy urine, although the proportion is liable to great variation, owing to the circumstance that the chloride of sodium is always derived from the food. The importance of this substance to the organism is sufficiently proved by the fact that all kinds of food contain a certain quantity, and almost every specimen of water holds some proportion in solution. Again, it is well known that the health of animals deprived of the proper amount of salt, deteriorates. It is to be detected in nearly all the tissues of the animal body, and is found in large quantity wherever cell-development is actively going on. This is true both with regard to healthy tissues and morbid growths. Common salt crystallises in cubes; but, in the presence of urea and some other organic substances, it assumes the form of a regular octohedron. As is well known, it is readily soluble in water (31·84 parts in 100), diffuses itself rapidly through a large bulk of fluid, and, in a dilute state, permeates tissues with great facility.

Besides common salt, urine also contains a certain quantity of chloride of potassium.

174. **Quantity.**—Healthy urine contains from three to eight grains of chloride of sodium in 1,000; the solid matter, about 6 per cent.; and the fixed salts, about 25 per cent. or more. Under ordinary circumstances, from 100 to 300 grains of salt are removed from the body in twenty-four hours; but the proportion is influenced by a great variety of circumstances, and is especially effected by the quantity of fluids taken. Dr. Parkes estimates the quantity of *chlorine* at from 92 to 124 grains in twenty-four hours. The amount is very variable in different individuals, according to the proportion

of salt taken with the food. The secretion of chloride of sodium, as would be supposed, attains its maximum a few hours after a meal, and but little is eliminated during the night.

175. **Detection.**—Chloride of sodium is very easily detected in urine. It is only necessary to acidulate the specimen with a few drops of nitric acid, and then add nitrate of silver. The white precipitate of chloride of silver is quite insoluble in nitric acid, but soluble in ammonia. In order to make a quantitative determination, the chloride of silver is to be dried; and it should be burnt and fused in a *porcelain* capsule before being weighed. The volumetric process, however, is the most accurate (§ 40).

176. **Circumstances affecting the Excretion of Salt.**—Chloride of sodium is not formed in the organism, but seems to exert some important and beneficial effects during its passage through the tissues; and whenever the nutritive changes are very active, there seems to be an unusual demand for chloride of sodium. But the precise part which the substance plays is at present unknown. The quantity of salt excreted in the urine undergoes great changes in certain diseases. The proportion also varies considerably from day to day, under the influence of an ordinary diet in health; and the ingestion of large quantities of water causes the elimination of a greatly increased amount of common salt. Thus, in one experiment, continued for four days, the following results were obtained: during the first three days, about thirty-six ounces of urine were passed per diem; the specific gravity varied from 1,015 to 1,024. The total quantity of solid matter passed in twenty-four hours was about 750 grains, and the chloride of sodium amounted to 113 grains. On the fourth day a large quantity of water was taken; 258½ ounces of urine, of specific gravity 1,003, were passed; containing a total of 1134·48 grains of solids, and 232·8 grains of chloride of sodium. The phosphoric acid was diminished, and the sulphuric acid was increased by upwards of one-third.

177. **Soda and Potash (NaO & KO).**—In healthy urine but a very small quantity of potassium is present in the form of chloride; but of soda salts there is a large proportion. The potash salts, as was first pointed out by Liebig, are found in considerable quantities in the muscles, while the soda salts predominate in the blood. Although

phosphate of potash be taken in the food, the corresponding soda salt, which is necessary to the blood, is still found in that fluid; and there can be no doubt that, in the organism, the chloride of sodium is decomposed by the phosphate of potash—a phosphate of soda and a chloride of potassium being formed.

To separate the sodium from the potassium in urine, a somewhat tedious analysis, of which I will just give a rough outline, is necessary. After destroying the organic matter by ignition, the whole of the phosphoric and sulphuric acids are removed, and the potassium and sodium converted into chlorides. A solution of bichloride of platinum is then added, and a chloride of potassium and platinum, and a chloride of sodium and platinum are formed. The potassium salt is most insoluble, and separates in the form of small octohedra, which do not polarize light. These may be separated by filtration. The sodium salt remains in solution, and may be obtained in the form of crystalline needles by concentrating the solution. These crystals exhibit the most beautiful colours when a ray of polarized light is transmitted through them.

178. **Lime (CaO)** may be detected in urine by dissolving the salts in acetic acid, and adding a little oxalate of ammonia to the filtered solution. Oxalate of lime is precipitated as a white, granular powder, which passes through the pores of a filter, unless the mixture be boiled previous to filtration. As already mentioned, lime occurs in urine as a phosphate, and occasionally as a carbonate. It forms a urinary calculus very rarely met with in man; but not uncommon in some herbivorous animals. The urine of the horse always contains a number of spherical masses, composed of carbonate of lime, which may be regarded as microscopic calculi. It has been proved by Mr. Rainey that the spherical form which crystalline matter sometimes assumes, depends upon the presence of viscid matter in the solution which contains the crystalline matter. These spherical crystals of carbonate of lime, so constantly found in horse's urine, may be exactly imitated by causing carbonate of lime to crystalize artificially from gum water or other viscid fluids. ("*The mode of formation of shells*," &c.)

179. **Magnesia (MgO)** must be precipitated as Ammoniaco-magnesian phosphate, from a concentrated solution of the salts after the

separation of the lime. The fluid should be evaporated to a small bulk, and when quite cold a little of the solution of phosphate of soda should be added to the mixture, rendered alkaline by the previous addition of ammonia. Unless there be already a sufficient quantity of ammoniacal salt in the mixture, some muriate of ammonia should be added, as the magnesian salt is slightly soluble in pure water, but insoluble in solutions of ammoniacal salts.

The solution should be stirred in all cases, for by this means a precipitate can often be produced, although before not the slightest turbidity was observable.

180. Iron (Fe).—Traces of iron may be detected in healthy urine if a large quantity of the secretion be operated upon. Like many other mineral substances, iron passes off in small quantities in the urine, and is generally found in the urine of persons taking preparations of iron. Dr. Harley has shown that iron is a constituent of one of the colouring matters of the urine. (*Uræmatine.*)

181. Silica (SiO_3).—Berzelius, many years ago, demonstrated the presence of *silicic acid*, or silica, in urine. Mere traces are met with in the ash after the removal of the salts insoluble in water, by the addition of strong nitric acid. The silica remains undissolved. This substance is derived principally from wheat, which, like other plants belonging to the cerealia, contains a considerable proportion of silica. Silica has been occasionally met with in urinary calculi, in appreciable quantity.

182. Alumina (Al_2O_3).—It has been stated by authorities that this substance does not pass off from the system in the urine at all; but from several observations which I made some years since, and which I have lately repeated, I have been led to conclude that it is very commonly present in the ash of urine. The alumina detected in the urine is in great part, if not entirely, derived from the alum taken in the bread. Some time since, while in the habit of eating pure home-made bread, I was unable to detect the presence of this substance in the manner presently to be described; but afterwards, when my diet consisted of baker's bread, I found very decided indications of its presence.

The test which has been employed is the ordinary blow-pipe test. A little of the fixed saline residue, which has been perfectly clear-

bonised, is moistened with a solution of nitrate of cobalt, and heated gradually in the blow-pipe flame to a bright red heat. If alumina be present, the bead, upon cooling, is found to be of a beautiful *bright blue* colour. As is well known, there is great difficulty in separating phosphate of alumina from phosphate of lime; and the ordinary process of analysis is not sufficiently delicate to detect this substance in the small quantity in which it ordinarily occurs in the ash of urine. When the ash contains as much as one-fiftieth part, however, I have been able to detect it by the liquid tests. The blow-pipe test above referred to is not without objection, inasmuch as any bead containing phosphates exhibits a blue colour when heated in the blow-pipe with nitrate of cobalt. The blue colour produced is certainly very different to that developed when alumina is present. A bead consisting of phosphates of soda, lime, and magnesia, gave a very dull grayish blue colour with the cobalt; but, when the slightest trace of alumina was added, a very bright and decided colour resulted. I have applied this test, therefore, to the urine salts before and after alum was taken in the food. In the first case, the blue tint was very undecided, or was not at all manifested; while in the last it was bright and distinct.

At a time when I was taking home-made bread perfectly free from alum, I examined the urine. The ash was tested for alumina with nitrate of cobalt in the usual manner, but only a faint blue colour was produced. Immediately after evacuating the bladder (12 noon), five grains of alum were taken, dissolved in an ounce and a half of distilled water. At 6 p.m., about fifteen ounces of urine were passed. A portion of this was evaporated to dryness, and the residue incinerated and decarbonised. A small quantity of the ash was treated with nitrate of cobalt, and heated in the blow-pipe flame. The bead, on cooling, was of a very bright blue colour. This experiment was repeated, with the same result. A similar reaction is met with in a great many specimens of ash obtained from the urine of hospital patients. Although this is not a perfectly accurate test, it indicates the presence of alumina in some specimens of urine in which one would expect a salt of this base to be present; while in urine which was perfectly free from alumina, no indication of its presence was afforded by the test. I think, therefore, if the cobalt test be employed carefully, it is worthy of more trust than most chemists seem disposed to place in it. A further series of researches

is required to prove the proportion of alumina removed in the urine to that which escapes by the intestinal canal, when salts of this base are taken with the food. But I think there can be little doubt that a certain amount of this substance is really carried off in the urine. The urine salts of most persons give a very decided reaction indicating the presence of this substance, a considerable quantity of which is taken with many kinds of bread. Although there are many objections to mixing alum with the bread, and the practice ought clearly to be put an end to, I am not aware that any deleterious effects have been produced by its introduction. Some have attributed habitual constipation to this cause.

It is desirable that the student should be acquainted with the principal characters of the most important inorganic salts of urine; and it has been considered desirable to give the following short course of systematic analysis. When it is required to estimate the proportion of chlorides, phosphates, or sulphates, quantitatively, the volumetric process will, however, be found the most accurate as well as the most expeditious.

Systematic Qualitative or Quantitative Analysis of Healthy Urine: Inorganic Constituents.

183. Analysis.—The portion of urine B, (p. 104), is also to be evaporated to dryness, and the dry residue incinerated in a large platinum capsule, and maintained at a dull red heat until it is perfectly decarbonised and nothing remains but an almost perfectly white ash. This, consisting of the fixed salts, is now to be examined as follows. Boiling distilled water is to be poured upon the saline residue, and the mixture thrown upon a filter.

The *solution* contains the *alkaline salts.*

The *insoluble matter*, consisting of *phosphate of lime, phosphate of magnesia*, and *silica*, remains behind on the *filter.*

1. The residue *insoluble in water* is to be treated with nitric acid, and boiled if necessary. *Silica* remains undissolved. If effervescence occur upon the addition of the acid, *carbonate of lime* was present in the ash. Filter; add excess of ammonia to the filtered solution, and redissolve the precipitated phosphates by adding excess of acetic acid. Next precipitate the lime as oxalate, by the addition of oxalate of ammonia. If the *quantity* of lime is required, the

oxalate must be heated, exposed to the action of a dull red heat in a platinum capsule, and weighed as carbonate.

After the separation of the oxalate of lime by filtration, concentrate the clear solution by evaporation, and add a little ammonia and chloride of ammonium. Stir the mixture, and set it aside, that crystals of *triple or ammoniaco-magnesian phosphate* may form.

2. The *original solution*, containing the urinary salts, soluble in water, is divided into two portions, 2 *a*, 2 *b*.

2 *a*. The first portion is acidified with nitric acid, and treated with *nitrate of silver*. *Chloride of silver*, indicating the presence of chlorine, is precipitated. The chlorine originally existed in combination principally with sodium.

2 *b*. The second portion is also to be acidified with nitric acid, and an excess of solution of nitrate of barytes added; a precipitate of *sulphate of barytes*, proving the presence of sulphuric acid, occurs.

The mixture is boiled and filtered; and, upon the addition of ammonia to the solution, *phosphate of baryta*, showing the presence of phosphoric acid, is precipitated, care being taken to prevent the formation of carbonate of baryta by exposure to the air.

Next the phosphate of baryta is to be separated by filtration; and the solution, which contains nitrate of barytes, ammonia, and the fixed alkalies, is to be concentrated. Excess of carbonate of ammonia and ammonia is to be added, and the mixture thrown upon a filter. The solution is to be concentrated by evaporation, and the barytes separated by sulphuric acid, after which the solution is to be evaporated to dryness, and the residue heated to redness in a hard glass tube, in the mouth of which a fragment of carbonate of ammonia has been placed. The residue is to be treated with water, and filtered. The solution contains the salts of the alkalies, *potash* and *soda*. The former is thrown down in the form of minute octohedral crystals of the *potassio-chloride of platinum*, upon the addition of a solution of bichloride of platinum. After stirring, these may be filtered off.

The solution contains the *sodio-chloride of platinum*. It is to be concentrated, in order that the beautiful acicular crystals of this substance may form.

The presence of the following substances in the specimen of urine submitted to examination, has been proved:

Fixed Salts.........................
- Lime ....
- Magnesia ....
- Potash.........................
- Soda ....
- Chlorine ....
- Phosphoric Acid ....
- Sulphuric Acid ....

The constituents not included in the above list, and in that on p. 106, require special processes for their demonstration; and, as many of them exist in very minute quantity, it is not desirable that the student should attempt to test for them in the small amount of urine usually operated upon. The substances alluded to are the following:—

Creatine.		Ammonia.	
Creatinine.		Hippuric Acid.	
Sarkine.		Iron.	
Uræmatine.		Alumina.*	
Uroxanthine.		Carbonic Acid.	
Phenylic Acid	?	Leucine	†
Damaluric Acid		Tyrosine	
Traces of Sugar.	?		

The characters of several of these have already been discussed, and the methods for separating them from the urine described.

* Not necessarily present in healthy urine.

† In urine in certain diseases. Probably not in healthy urine.

CHAPTER VIII.

COMPOSITION OF HEALTHY URINE, AND THE QUANTITY OF THE DIFFERENT CONSTITUENTS EXCRETED IN TWENTY-FOUR HOURS.—*Analyses of Healthy Urine—Total Quantity in twenty-four hours—Quantity in proportion to a given weight of the body—Variation in Quantity at different ages—Average Composition of Healthy Urine—Observations on estimating the Excrementitious Matters—Weighing Machines.*

184. **Average Composition of Healthy Urine.**—It is clearly very important that we should form a general idea of the quantitative composition of healthy urine, and the amount of the various constituents which are excreted from the healthy organism in twenty-four hours. Those who are making observations on the urine in disease, should be acquainted also with the relative proportion of these different substances to each other. It is true that the healthy variations are very great; but, in certain cases of disease, the difference in the quantity is so considerable that the observer cannot fail to be struck with the importance of the fact. Thus, in health, from 400 to 500 grains of urea are excreted in twenty-four hours. In certain cases of kidney-disease, when the cortical portion is impaired in structure, not more than 100 grains are eliminated; while, in some cases of fever, upwards of 1,000 grains have been removed in the same time. Of the significance of such facts there can be no question; and the physician cannot fail to reflect upon the very different chemical conditions under which life is being carried on in these cases. Without considering all the circumstances likely to affect these abnormal processes, how can we

hope ever to gain that insight into the nature of disease which, in many instances, can alone enable us to modify or counteract the morbid changes going on?

185. Analysis of Healthy Urine.—The composition of healthy urine is given in analyses by Berzelius, Lehmann, and Dr. Miller.

A is an analysis of 1,000 parts of healthy urine by Berzelius; B is one by C. G. Lehmann.

	A		B	
Water	933·00		932·019	
Solid matter	67·00	100·0	67·981	100·0
Urea	30·10	44·9	32·909	48·4
Uric acid	1·00	1·4	1·098	1·5
Lactic acid	17·14	25·5	1·513	2·3
Lactates			1·732	2·6
Water extract			·632	1·0
Spirit and alcohol extract			10·872	16·0
Chloride of sodium	4·45	6·6	3·712	5·5
Chloride of ammonium	1·50	2·2		
Alkaline sulphates	6·87	10·2	7·321	10·8
Phosphate of soda	2·94	4·3	3·989	5·9
Biphosphate of ammonia	1·65	2·4		
Phosphates of lime and magnesia	1·00	1·4	1·108	1·7
Mucus	·32	·4	·110	·3
Silica	·03	·04		

The following is an analysis of healthy urine by my friend Dr. W. A. Miller, of King's College:—

Specific gravity		1,020	
Water		956·80	
Solid matter		43·2	100·00
Organic 29·79	Urea	14·23	33·00
	Uric acid	·37	·86
	Alcohol extract	12·53	29·03
	Water extract	2·50	5·80
	Mucus	·16	·37
Fixed salts, 13·35	Chloride of sodium	7·22	16·73
	Phosphoric acid	2·12	4·91
	Sulphuric acid	1·70	3·94
	Lime	·21	·49
	Magnesia	·12	·28
	Potash	1·93	4·47
	Soda	·05	·12

186. Total Quantity of Substances excreted in Twenty-four Hours.—But it is most important to be acquainted with the total quantity of the different ingredients excreted in twenty-four hours.

The urine passed during the entire period of twenty-four hours should be collected and measured. From the results obtained, by analysing a portion of this, the total quantity of the different ingredients in the whole amount passed is easily calculated. The quantities of the different substances excreted in twenty-four hours, is stated under their proper heads, and a rough approximation of each is given in the table on p. 136.

Vogel gives the following estimate of the quantity of urine and its most important constituents excreted in twenty-four hours in a state of health:—

Average quantity in twenty-four hours . .	$52\frac{3}{4}$ to 56 oz.
Average specific gravity	1·020
Average quantity of urea	556 grains.
Average quantity of chlorine	154 ,,
Average quantity of free acid	33 ,,
Average quantity of phosphoric acid . .	66·7 ,,
Average quantity of sulphuric acid . . .	30·88 ,,

187. Proportion excreted for each pound weight of the Body.— The relation of the quantity of urinary constituents excreted, to the weight of the body, is also a most important inquiry, and is generally stated at so much for each pound weight.

The following results, taken from Dr. Parkes, give the quantity of urinary constituents excreted for each pound weight of the body in twenty-four hours, adopting 145 lbs. as the average weight of all the men whose urine had been analysed.

Water	158·639 grains.
Urea	3·530 ,,
Uric Acid	·059 ,,
Creatine	·032 ,,
Creatinine	·048 ,,
Pigment and Extractives	1·062 ,,
Sulphuric Acid	·214 ,,
Phosphoric Acid	·336 ,,
Chlorine	·875 ,,

The table below is taken from a valuable paper by the Rev. S. Haughton, in the "*Dublin Quarterly Journal*," October, 1862. The results accord very closely with those just given.

	Excreted in 24 Hours.	Excreted in 24 Hours per pound of the body Weight.
Urine	23021·25 grains.	155·348 grains.
Water	22063·44 „	148·381 „
Solid Matter	957·81 „	6·467 „
Urea	493·19 „	3·331 „
Uric Acid	3·15 „	0·021 „
Phosphoric Acid	32·36 „	0·218 „
Sulphuric Acid	31·55 „	0·214 „
Chlorine	106·56 „	0·673 „
Extractives	175·27 „	1·183 „
Balance (viz. inorganic bases) .	115·73 „	0·827 „

188. Variation of Quantity at different periods of life.—The proportion of the different constituents excreted varies, however, as already stated, at different periods of life. The amount of urine excreted, is much greater in proportion to the body weight in children, than in adults. In the fœtus and infant, however, the urine contains a very small quantity of solid matter. In a specimen of fœtal urine, examined by Dr. Moore (Heller's pathology of the urine), no urea was present. I found urea in a specimen taken at the seventh month. It contained also numerous casts of the uriniferous tubes with free epithelium but no albumen. The proportion of solid matter is not more than five parts in 1,000.

In young children of from 4 to 8 years, the mean age being 4 years and 2 months, and the mean weight 31 lbs., the quantity and composition as calculated from analyses by Scherer, Bischoff and others, by Dr. Parkes, is as follows:—

	In 24 Hours.	Per lb. of the body weight in 24 Hours.
Water	10062·0 grains = f ℥ xxiij.	3282·00 grains.
Solid Matter	426·0 „	13·70 „
Urea	178·8 „	5·77 „
Extractives	60·7 „	1·96 „
Fixed Salts	186·9 „	6·03 „

In old age, on the other hand, the solids of the urine are considerably lessened. According to Lecanu, only 125 grains of urea were excreted in twenty-four hours by old people. The uric acid was about the ordinary proportion.

Although, in all works on the urine, tables of the average composition of urine are given, it must not be supposed that the numbers given are true for every individual case. It has been clearly shown, not only that the proportion varies according to the weight of the person, the quantity of food taken, the amount of active excercise, and many other circumstances, but that the proportion of solid matter excreted for every pound weight of the body varies considerably in different individuals, in the same person at different times, and enormously at different periods of life. This, however, is no more than would be expected, since the proportion of the most important of the solid urinary constituents depends directly upon the quantity of matter disintegrated in the organism; and this, as is well known, is much greater in the child than in the adult; while in old age these changes are reduced to a minimum.

189. Average Composition of Healthy Urine, &c.—With a view of giving a rough idea of the general amount of the different urinary constituents excreted, and the proportion which these bear to each other, in twenty-four hours, I have arranged the results of numerous observations in a tabular form. The proportion of some of these substances is so variable, that it is impossible to give an average. In most cases, I have purposely given a round number, and avoided fractional parts; but in other instances, in which I have not been able to institute examinations for myself, and when the question has only been examined by one or two observers, I have given the exact figures published by the authority who has made the matter an object of special study. In constructing this table, I have not attempted to follow any single observer, but, with the exceptions alluded to, have put down numbers which appear to me to be tolerably correct. They have been obtained by consulting numerous authorities, and from my own analyses. This table, therefore, is only to be looked upon as a rough approximation to the truth. In the second column will be found the quantity of each constituent corresponding to every pound weight of the body eliminated in twenty-four hours; in the third column the composition of 1,000 grains of urine is given; in the fourth, the quantity of constituents in 100 grains of solid matter; and in the fifth, the percentage composition of the salts.

The figures in the table may be regarded as the proportion

excreted by a strong healthy man in good nutrition, on full diet. Healthy women would excrete from one-third less to half the quantities given in the first column.

Some exception may be taken to the numbers expressing the *relative* amount of the different ingredients. For instance, the proportion of urea to extractive matters undergoes the greatest variation. Sometimes the urea is double the weight of the extractives, while in other cases the numbers would be almost reversed. Many of the saline constituents also exhibit the greatest variations, not only in different individuals, but in the same person, on different days. Thus the quantity of chlorides is twice as great on some days as on others; depending, as before remarked, partly on the amount taken in the food, partly upon the quantity of fluid and other saline matters. As yet, these extraordinary fluctuations have not fully been accounted for; but, doubtless, in time, the circumstances which determine them will be accurately made out.

Table showing the amount of Urinary Constituents excreted in twenty-four hours, and in 1,000 *parts of Healthy Urine, with the percentage composition of the Solid Matter and Fixed Salts.*

	Excreted in 24 hours.	Excreted for every pound weight of the body, of an adult weighing 145 lbs., in 24 hours. ‡	In one thousand parts of urine.	In one hundred grains of solid matter.	In one hundred grains of salts.
Specific Gravity 1,015 to 1,025					
Quantity	40 oz. to 60 oz. 17,500 grs. to 26,250 grs.				
Water	16,700—25,050	About 158·63	968·0 —940·0		
Solid matter	800— 1,200	„ 8·00	32·0 — 60·0	100·0	
Organic matter	600·0—900·0	„ 6·0	24·0 — 45·0	75·0	
Saline matter	200·0—300·0	„ 2·0	8·0 — 15·0	25·0	100·00
Urea	400·0 —600·0	„ 3·53	12·0 — 30·0	45·0	
Kreatine	3·45*— 6·32*	„ ·03			
Kreatinine	5·50*—10·00*	„ ·05	·3 — 1·0	1·5	
Uric Acid	5·00 — 8·00	„ ·06			
Hippuric Acid	7·50*—30·00†				
Extractives and colouring matter	140·0 —200·0	„ 1·06	9·0 — 20·0	20·0	
Free Acid	20·0 — 30·0		·32— ·64	1·0	
Ammoniacal Salts	6·0 — 15·0		1·50— 3·00	5·0	
Mucus	10·0 — 30·0		·1 — ·4	1·0	
Sulphates	50·0 — 85·0		1·5 — 6·0	8·0	30·0
Alkaline Phosphates	60·0 —100·0 or 16		2·0 — 9·0	9·0	38·0
Earthy Phosphates	6·0 — 20·0		·5 — 1·2	1·5	6·0
Chlorides	100·0 —300·0		4·0 — 8·0 or more	7·0 or more	25·0 or more
Chlorine	60·0 —180·0	·88	2·4 — 4·8	about 4·2	15·1
Sulphuric Acid	25·0 — 42·0	·21	·75— 3·0	about 4·0	15·0
Phosphoric Acid	30·0 — 50·0 or 80	·34	1·0 — 4·5	about 4·5	19·0

The numbers in the first column are *high*, and must not be considered to represent the smallest proportions excreted consistent with health.

* Thudichum. † Hallwachs. ‡ The numbers in this column are taken from Dr. Parkes.

190. Observations on Estimating the Excrementitious Substances.—The above table may, perhaps, assist the practitioner in some measure, in remembering the general composition of healthy urine, and the proportion of the different constituents eliminated from the body in twenty-four hours. It is, however, quite impossible to use this or any other table as a standard of reference, because the proportion of the urinary constituents secreted in health is very different in different individuals. Before we can judge if a man is passing too much or too little of any substance, we must ascertain his weight, and form some general idea of the activity of his vital actions when he is in a state of health. For example, the statement that a patient is passing daily 150 grains of urea, indicates nothing; for a small woman in good health, weighing 80 lbs. or less, secretes daily even less than this; but if this amount only were excreted by a tall, strong, active, healthy man, weighing 170 lbs. or more, it would indicate a very serious condition, and we should know from this fact alone that he was in the greatest danger. The secreting structure of his kidneys must be temporarily or permanently affected, and, unless relief could be afforded very soon, death would probably result from the accumulation of excrementitious substances in the blood. If it is proposed to conduct a series of researches with the object of ascertaining the proportion of excrementitious substances produced in, and removed from, the organism, the weight of the individual should always be taken, and the amount of ingesta must be estimated daily. The quantity of excrementitious substances generally, including the sweat, if possible, must be estimated. There is very much to be made out by carefully conducting series of researches of this kind in the cases of patients suffering from various acute affections; and, since the introduction of the volumetric process of analysis, we have had great facilities for conducting such inquiries.

191. Weighing Machines.—In many cases, the most valuable information bearing upon the progress of the case may be gained by the simple process of weighing the patient, which is too seldom adopted. All our hospitals and public institutions ought to be furnished with weighing machines. How often in the course of many diseases one desires to know simply if the patient has gained or lost in weight? The best weighing machines are, unfortunately,

very expensive. A good simple apparatus, which can be made for a moderate sum, is much required. Messrs. Weiss construct an improved apparatus suitable for the practitioner, but the price of this is ten guineas. Mr. Young of Cranbourne Street, W.C., also makes excellent weighing machines. A very useful machine is supplied by Messrs. Pooley, of Liverpool, and Fleet Street, London, which is well adapted for ordinary observation, and costs less than four pounds.

CHAPTER IX.

Urine in Disease.—Diathesis.—Excess or Deficiency of Water and the Organic Constituents present in Health. *Excess of Water—Diabetes Insipidus—Deficiency of Water—Clinical Remarks on the increased Acidity of Urine—Nitric Acid in the Urine—Alkaline Urine—Uræmia—Ammonia—On Detecting Urea in the Blood or Serum—On Detecting Ammonia in the Breath—Urea—Excess of Urea—Clinical Observations—Deficiency of Urea—Colouring Matter—Tests for Uroxanthine—Colouring Matter of the Blood—Black Pigment—Excess of Uric Acid and Urates—Treatment—Hippuric Acid—Extractive Matters—General Remarks on the Increase of the Organic Constituents—Analyses of Urine in Skin Disease—Analyses of Urine in Chorea.*

Urine in Disease.

192. **Morbid Urine.**—Before I describe in detail the particular characters in which a specimen of urine may differ from the secretion in its normal state, it is desirable to consider one or two questions of general interest, which can be more advantageously discussed here than in a future chapter.

Many alterations in urine, which have been termed "*morbid*," really depend upon increased or diminished activity of the same chemical changes which occur in health. It is often very difficult to decide how far an alteration in the quantity or quality of the constituents should be attributed to physiological changes, or referred to morbid actions; and it is quite impossible to separate by a distinct line, healthy from morbid actions. An excess or deficiency of the ordinary normal changes may lead to disease. There are many

alterations in the urine, depending upon a temporary derangement of those actions which occur in a state of health, which would not be properly described under the term healthy, but which, nevertheless, cannot properly be called morbid. I do not attempt, therefore, to divide *accurately* healthy urine from morbid urine, and only wish the arrangement adopted in this work to be regarded as a sort of rough artificial division, adopted for convenience alone. Indeed, all such divisions are quite artificial; and no one attempts to assign accurate limits even to large and important branches of natural science, as anatomy, physiology, histology, botany, medicine, surgery, &c., which, merely for convenience, are treated of as separate subjects.

Important changes often occur after the urine has been passed, and may be due to the action of the air, fermentation caused by the presence of mucus, and a number of other circumstances.

The functions of digestion, respiration, and circulation, are intimately concerned in the formation of those substances which are removed from the system in the urine. The characters of the secretion are much affected by the state of the skin and the action of the liver; and there are many other circumstances which may cause an alteration in the urine, independently of those numerous affections to which the urinary organs are exposed. Disease of the secreting structure of the kidney, or of any part of the complicated and extensive efferent channel by which the urine is carried off from the gland, may cause very important alterations in the characters of the secretion. It is of great importance to us, as practitioners, to know that an examination of the urine may materially assist us in endeavouring to ascertain the exact nature and precise seat of the derangement in cases of renal disease, and of the mucous surface and organs connected with the urinary apparatus. Sometimes we are able to diagnose the morbid alteration from an examination of the urine alone; but in almost all cases such an examination will afford important information bearing on the nature of the case. Certain substances, which are ordinarily eliminated in the urine, may, in consequence of morbid actions having been set up, be attracted to other parts of the body, or be eliminated through other channels.

When the kidney itself is affected, the morbid condition may be temporary or permanent; and this can often be ascertained with certainty by examining the urine. The mucous membrane of the

pelvis of the kidney, of the ureter, or of the bladder, may be the seat of the lesion; or lastly, a certain effect may be produced by the growth of adjacent tumours, by causing pressure, altering the structure of the organs, &c.

The *ordinary constituents* may be in greater or less proportion than in health, or certain *soluble substances* not met with in the healthy secretion may find their way into the urine. As I have before remarked, a little mucus from the urinary passages is the only *deposit* which occurs in health. In disease, *insoluble deposits* are commonly met with. Substances which are comparatively, though perhaps not absolutely, insoluble (being soluble in a very large quantity of the secretion), may float upon the surface of the urine, or may be suspended throughout the fluid.

By *microscopical examination*, combined with chemical tests, the nature of a deposit is made out. By *chemical analysis* alone, an abnormal proportion of substances present in health, and the presence of such as are not found in the healthy secretion, can be detected, and the amount estimated.

The various alterations of the urine in disease will be discussed in the following order.

First, excess or deficiency of any of the normal constituents of urine. Secondly, I shall refer to the characters of certain soluble substances in the urine in disease, which are never met with in a state of health. The subject of *urinary deposits* will be subsequently considered.

Diathesis.

193. Diathesis.—The word *diathesis* is very frequently used in connection with certain abnormal states of the urine. Before considering the characters of the urine in disease, it is therefore desirable to discuss what is understood by this word. The "uric acid," the "phosphatic," the "oxalic," the "sulphuric" *diatheses*, and others, are constantly spoken of. It is well to consider whether any real advantage is gained by employing this term in the manner in which it is generally used. Although the word has been employed by very high authorities since the time of Dr. Prout, there is great objection to its use as an explanation of the causes of the production of urinary deposits.

In the first place, with reference to the *uric acid diathesis*; this

term has been applied to all cases in which the urine habitually contains deposits of uric acid and urates. The precipitation of uric acid in an insoluble form is due to a change taking place in the urine, at least in the majority of instances, *after* it has been secreted. Excess of uric acid may exist in the urine in two states, *dissolved in the fluid*, and in the form of an *insoluble deposit*. In the first case, the practitioner would not be cognizant of the excess; and a person may be passing a very considerable quantity of urates, in a state of solution, for a long time, without any notice being taken of the fact. On the other hand, a patient's urine may contain only the healthy proportion of uric acid; but this, owing to a change taking place *after* it has left the bladder, might be deposited in an insoluble form. From this circumstance alone, it would be inferred that the last patient had a disposition to the formation of a large quantity of uric acid (*uric acid diathesis*), while really there might be a much larger amount produced and excreted in the former instance.

Secondly; persons whose urine has deposited triple phosphate and phosphate of lime have been said to suffer from the phosphatic *diathesis;* while the deposition of the sediment depends, at least in the great majority of cases, upon a change occurring in the urine after it has left the secreting part of the organ, and has not necessarily anything to do with the habit of body or peculiarity of constitution, or with the state of the blood. But the deposition may be associated with actual and positive excess. Dr. Bence Jones defines the phosphatic diathesis and the sulphuric diathesis in the following terms: —"What I wish to impress upon you now is, that the true phosphatic diathesis—that is, the occurrence of an excess of alkaline and earthy phosphates in the urine—may not make itself apparent to the eye. The alkaline phosphates may be present in an inordinate excess; and, as in the sulphuric diathesis, the sulphates may be immensely increased," &c. (Lectures on Digestion, Respiration, and Secretion, "*Medical Times and Gazette*," March 27th, 1852.)

Now, in these cases, what is observed is, that a greater proportion of certain constituents is excreted in the urine than occurs in perfect health. The different physiological conditions under which an excess of some of these substances is produced are well understood, and the result cannot be referred to any peculiar *habit* or *diathesis*. If we speak of the *sulphuric acid diathesis*, we must, of

course, admit the *urea diathesis;* for usually, when the sulphates are in excess, a corresponding increase in the proportion of urea exists. On the same principle, we might speak of the *extractive diathesis* and the *water diathesis.* It would be quite as fair to talk of the *carbonic acid diathesis* when an increased proportion of carbonic acid was exhaled, &c.

Thirdly; many of the above remarks will apply to the so-called *oxalic diathesis.* The presence of oxalate of lime, and the increase of certain of the materials which exist in health, depend upon the action of well-known chemical changes, and result as the natural consequence of confinement, exposure to cold, particular kind of food, &c. No peculiar diathesis can be discovered in persons who pass urine having these characters: in fact, in the majority of cases, the alteration is only of temporary duration; and it therefore seems to me, that the term *diathesis* is quite inapplicable.

We may in the present state of knowledge, with propriety, perhaps, speak of the *gouty diathesis,** of the *tubercular* and *cancerous diathesis*, and, perhaps, of the *rheumatic diathesis,* because there certainly is a peculiarity of constitution, which may be transmitted from parent to offspring, and which is characterised by the invariable presence of certain morbid actions which exist in the conditions familiar to us, under the terms *gout*, *tubercle*, *cancer*, and *rheumatism.* But of the actual state of the blood, and condition of the vital processes, which lead to the symptoms with which we are so familiar, we really know very little; so that it seems to me better, even in these cases, to say that a patient suffers from attacks of gout, of tubercle, cancer, or rheumatism, than to hide our ignorance of the essential nature of these morbid states under a learned term, the meaning of which cannot be well defined. I shall venture then to discard altogether the use of the word *diathesis* in the discussion of morbid states of the urine.

Excess or Deficiency of Water and of the Organic Constituents of Urine.

194. **Water.**—The varying quantities of water removed from the body, in different physiological states of the system, have been

* Dr. Garrod has shown that, in gout, the kidney fails to excrete the uric acid in the usual quantity.

already referred to. Every one is familiar with the relations existing between the functions of the skin and intestinal canal, and the kidneys. The same laws hold in disease. If the kidneys be diseased, and the intestinal canal, the skin, and the respiratory apparatus, be tolerably healthy, they, to some extent, fulfil the work of the kidneys. In skin diseases, and in certain affections of the intestinal canal, increased work is thrown upon the renal apparatus. In the treatment of these cases, the practitioner must bear in mind the existence of such relations.

There are certain affections in which the quantity of water removed from the body is greatly increased. In various hysterical and other emotional states, large quantities of pale urine, containing but a small quantity of solid matter, are frequently voided. Some persons habitually pass very dilute urine, which is not very easily explained, but is probably to be looked upon as an individual peculiarity, corresponding to the constant sweating, and to the unusual amount of action of the alimentary canal, occasionally met with in individuals who enjoy good health.

It has been already remarked, that within certain limits water increases the disintegration of tissue; and when a large amount of fluid is taken, the total quantity of solids removed in the urine is greater than in health. When the solids as well as the water are greatly increased in quantity, we should be led to fear the existence of diabetes (Chapter XII.). An unusual quantity of urine of very high specific gravity, and therefore containing a large amount of solid matter, is almost characteristic of this condition.

195. Diabetes Insipidus.—The majority of the so-called instances of diabetes insipidus are cases in which there is great thirst, and a large amount of water is removed from the kidneys daily (*diuresis*); but the total quantity of solid matter is not above the normal standard. In a few of the cases recorded, it would appear that the latter is also much increased; but these must be very rare. There is no sugar in these cases. I have seen instances in which the quantity of water passed as urine was two or three times as great as that said to have been taken in the food; but I firmly believe that deception was practised, and that the patient got water by stealth. In some cases, however, in which very large quantities of urine are voided, there is undoubted evidence of

chronic renal disease. In Vol. II. of my "*Archives*," Dr. Eade alludes to several cases of this disease, and gives notes of two which occurred in men of the ages of 65 and 40. Two of the cases were children. The urine passed by the men amounted to from five to seven pints. Its specific gravity varied from 1,003 to 1,014. The man aged 65 suffered from severe irritation of the bladder, and died in eighteen months. The *post mortem* revealed a bloodless state of the viscera generally. The coats of the bladder were much thickened; the infundibula and pelves of the kidneys much dilated; the left kidney was of the natural size; the right, one-half larger, the cones very hard, pale, and flaccid. In the other fatal case, both kidneys were much wasted. The cones "converted into dense fibrous tissue, containing many large cystiform spaces"; the pelves much enlarged, and the ureters a little dilated. Both supra-renal bodies were "converted into flaccid cysts, capable of containing each some half-ounce of fluid, with their walls having a bile-coloured granular appearance." Dr. Eade sent me the kidneys for examination. I found that many of the tubes in the cortical portion were narrow and much wasted; others were twice the diameter of the tubes in health. The walls of the tubes were thick and firm; the Malpighian bodies were smaller than in health; the epithelial cells smaller and more numerous. The state of the supra-renal bodies in this case has led Dr. Eade to offer the suggestion, that the condition might have originated in some irritative disorder of the supra-renal bodies. ("*Archives of Medicine*," Vol. III., p. 127.)

The following analysis represents the composition of the urine in one of these cases of Hydruria, or diabetes insipidus. It was obtained from a man aged 45, in King's College Hospital, under Dr. Todd. This patient was passing about eleven pints of urine *per diem*, while he was drinking about thirteen pints of liquid. Reaction feebly acid; specific gravity 1002·8.

Analysis 1.

			In 24 hours.
Water	995·91		
Solid Matter . . .	4·09	100·00	394
Organic Matter . .	2·79	68·22	268
Fixed Salts . . .	1·30	31·78	125

The quantity of urea excreted in twenty-four hours in this case was very small, which confirms the observation of Bischoff, that the

ingestion of a large quantity of water diminishes the exeretion of urea. At first, the total quantity passed in twenty-four hours is above the average, beeause much is washed out from the tissues by the large quantity of fluid; but afterwards it falls, because less is formed in the organism than under ordinary circumstances. The proportion of inorganic salts to the organic eonstituents of the urine is very high, though the total quantity is less than is passed in health.

In one of Dr. Eade's eases, an analysis of the urine was made by Mr. Sutton. It contained only 9·3 grs. of solid matter in 1,000 grs.; of this, 5·57 grs. eonsisted of urea. The composition of 100 grs. of the *solid residue* was as follows :—

Analysis.

Urea	60·00
Potash	5·63
Lime	·49
Soda and Magnesia	11·14
Silica	·43
Ammoniacal Salts, &c.	8·62
Sulphuric Acid	3·07
Phosphoric Acid	2·97
Chlorine	7·66

Dr. Strange, of Woreester, has published a very interesting case of diabetes insipidus. ("*Archives of Medicine*," Vol. III., p. 276.) The patient was a boy aged 18, with excessive thirst. He was of small build, but moderately stout. The urine amounted to twelve pints in twenty-four hours, and this large quantity had been passed for years. The specific gravity was 1,007. There was no albumen or sugar. The eomplexion was ruddy, and there was no pallor or puffiness indieative of renal disease. On admission into the infirmary he was only allowed a limited quantity of fluid to drink, and he was treated with phosphoric acid and nux vomiea. Catechu and laudanum were afterwards given to restrain the diarrhœa from which he was suffering. About ten days after admission he became drowsy. A fortnight after admission he was seized with convulsions, and soon beeame eomatose, with dilated pupils and stertorous breathing. The insensibility passed off after he was bled, but again reeurred two days afterwards, and soon became profound. He died

with symptoms of cerebral effusion. Both kidneys were reduced to "mere sacs, of from twice to thrice the extent of the healthy kidney! There was complete absence of all proper parenchymatous structure, both tubular and cortical, the sacs being divided into a number of cells by the septa which occur in the fœtal state." The *circumference of the ureters varied from three to four-and-a-half inches.* No urea was found in the fluid in the ureters and sacs. Dr. Strange considers that the condition of the kidneys was mainly due to congenital malformation. He thinks it probable that the sacs were only capable of separating the urea from the blood when in a very dilute form, and considers that the diarrhœa and the diminished quantity of fluid ingested may perhaps have somewhat hastened the fatal result. In all cases of this condition, there is an abundant flow of urine, depending upon the sufferers being excited to drink largely to allay the excessive thirst which they experience. There are languor, debility, loss of appetite, often nausea and vomiting, with weak heart's action, and general loss of power, and sometimes an irritable state of bowels, with diarrhœa. It is certain that many very important points connected with this very interesting disease are yet to be discovered. Every case should be very carefully observed.

196. **Treatment.**—Two of Dr. Eade's cases improved under tonics and iron. The quantity of fluid allowed should be reduced very cautiously. Dilute mineral acids, especially phosphoric acid, sometimes allay the thirst. The state of the patient's health generally must be considered; and if chronic renal disease exists, the treatment must be conducted according to the general plan followed in this condition. Of all mere remedies, the greatest benefit results from the tincture of sesquichloride of iron, steadily persevered in for months. But the practitioner will, of course, study the whole state of the patient, and not attempt merely to diminish the excessive diuresis.

197. **Deficiency of Water** is, in the great majority of cases, associated with an abnormal quantity of solid matter. The ingredient which is usually in excess, and to which the urine owes its great density, is urea; so that urine of this character will be more conveniently considered presently. There are cases in which a very small quantity of urine, containing but a small percentage of solid

matter, is passed; but in these *albumen* is generally present, and they will be considered in Chapter XI. When the total amount of urine is very small, and the secretion contains but little solid matter, the secreting structure of the kidney is generally much impaired.

198. Clinical Remarks on the Increased Acidity of Urine.—The causes of the reaction of healthy urine have been already considered in § 119, and it is therefore unnecessary to pursue this part of the subject further. Vogel states that, in chronic and acute diseases, the quantity of free acid is diminished for the most part. In many cases of pneumonia and rheumatic fever, however, the quantity of free acid is much greater than in health.

A highly acid condition of the urine, persisting for a long period of time, may cause the precipitation of uric acid, and so lead to the formation of a calculus. Acid urine not unfrequently causes irritable bladder, and excites other morbid actions. In most cases, the salts of the vegetable acids (citrates, acetates, tartrates), will be found more efficient in counteracting this acid state of the urine, than alkalies or their carbonates, and are less likely to interfere with the digestive process. There are, however, low conditions of the system in which the acid state of the urine, and a tendency to the deposition of uric acid in large quantity, are not relieved by this treatment; on the contrary, such cases are often much benefited by an opposite plan of treatment—tonics and the mineral acids before meals, a nourishing diet, with a moderate supply of simple stimulants with a little alkali, or with alkaline waters. Pepsine is often of great use in these cases. Many of them seem to be intimately connected with impaired digestive power. The acid state of the urine may depend upon very different conditions of the system, and these must be carefully considered in each individual case before any plan of treatment is suggested.

199. Nitric Acid in the Urine.—Dr. Bence Jones ("*Philosophical Transactions*," 1851, p. 399) has been led to the conclusion that ammonia, in its passage through the organism, gives rise to the production of a certain quantity of nitric acid, which is eliminated in the urine. He found that the acidity of the urine was not diminished by giving large quantities of carbonate of ammonia; and that, in some instances, the acid reaction seemed to be increased.

While tartrate of potash soon rendered the urine alkaline, this effect was not produced by the corresponding salt of ammonia.

The following test, suggested by Dr. Price, was employed for the detection of the nitric acid, in preference to the indigo test. By this plan, one grain of nitrate of potash dissolved in ten ounces of urine was detected with the greatest certainty. From four to eight ounces of urine were mixed with half an ounce of strong and pure sulphuric acid, free from nitrous acid. Two-thirds of the mixture were distilled over; and, after being neutralized with pure carbonate of potash, the distillate was evaporated to a very small bulk. From a drop, to half of the residue, was mixed with the following test-solution. To a solution of starch, a drop or two of a solution of iodide of potassium, specific gravity 1,052, and very dilute hydrochloric acid, specific gravity 1,005 were added. If nitric or nitrous acid is present, the iodine is set free, and a blue iodide of starch is at once formed.

Another portion of the residue was placed in a basin, and a very small quantity of indigo, with excess of sulphuric acid, added. If nitric acid was present, upon applying heat for a few minutes, the colour of course disappeared.

From numerous experiments, varied in many ways, Dr. Bence Jones came to the conclusion that ammonia in the organism is partly converted into nitric acid. The nitrogen of the air also, in ordinary combustion, unites with oxygen to form nitric acid. Urea and caffeine, and other substances containing nitrogen, give rise to the formation of a small quantity of nitric acid. Although Lehmann has failed to confirm these results, he has not, I think, succeeded in shaking the evidence in favour of the conclusions.* Dr. Bence Jones brings forward several cases of healthy persons whose urine did not yield a trace of nitric acid; but, three or four hours after they had taken carbonate of ammonia, evidence of the presence of the acid was afforded by the starch and also by the indigo test. After twelve hours, only a trace could be detected; and, in twenty-four, even this ceased to be perceptible. The urine was examined in precisely the same manner in every case. A small amount of ammonia in the

* Professor Lehmann attributed the action upon the iodide of potassium to the presence of *sulphurous acid*. Jaffé performed some experiments in Lehmann's laboratory, and obtained sulphurous acid but no nitrous acid from healthy urine and from urine passed after taking ammoniacal salts. Dr. Bence Jones has subsequently repeated his experiments, and finds that Jaffé's experiments do not invalidate Price's test for nitrous acid as Lehmann supposed. ("*Proceedings of the Royal Society*," Vol. VII., p. 94.)

organism is converted into nitric acid; and it is not improbable that, under certain circumstances, the quantity of nitric acid formed in this manner may be very much increased.

200. Alkaline Urine.—An *alkaline condition* of the urine may be due to several causes, and requires, therefore, to be treated on different plans. The connexion between an alkaline state of the urine, depending upon fixed alkali, and the secretion of a highly acid gastric juice, has been already referred to. In such cases, attention must be paid to the state of the digestive process; and when this is set right, the urine will regain its normal characters. Dr. Bence Jones ("*Medico-Chirurgical Transactions*," Vol. XXXV.) alludes to three cases of dyspepsia with vomiting of a very acid fluid (two of them rejecting sarcinæ), in which the urine became alkaline from the presence of fixed alkali when the quantity of acid set free at the stomach was very great; but, when this was small, the reaction of the urine was acid. It must, however, be borne in mind that the very acid nature of the materials rejected in many cases of vomiting, and especially in cases of sarcina ventriculi, arises, not from the secretion of an acid fluid by the glands of the stomach, but from the decomposition or fermentation of the food when acids are developed, among which may be mentioned acetic, lactic, and butyric acids. At the same time, there can be no doubt that, in many cases of dyspepsia, the feebly acid or alkaline condition of the urine arises from the secretion of an abnormal amount of acid by the stomach. "The degree of the acidity of the urine may, to a certain extent, be regarded as a measure of the acidity of the stomach." (Dr. G. O. Rees, "*Lettsomian Lectures*," 1851.)

Dr. Rees has drawn attention to a large class of cases in which he explains the alkaline condition of the urine as follows:—Urine which is highly *acid* at the time of its secretion, irritates the mucous membrane of the bladder, and causes it to secrete a large quantity of *alkaline fluid*. This mucous membrane in health secretes an alkaline fluid, to protect its surface, just as occurs in the case of some other mucous membranes. Under irritation, more alkaline fluid than is just sufficient to neutralise the acid of the urine is poured out; and hence the urine, when examined, is found to have a very alkaline reaction. In such cases, this highly alkaline condition is removed by giving liquor potassæ or some other alkali, or a salt of a vegetable acid which becomes converted into an alkali in the system. The urine

is not seereted so aeid, and therefore does not stimulate the mueous membrane to pour out so mueh alkaline fluid. I know no observations to disprove Dr. G. O. Rees' explanation of the faet, that in some eases, *alkalies cause the urine to become less alkaline, or even restore its acid reaction;* yet one would hardly expeet, if this be the true explanation in eases generally, that the natural reaetion of urine would be aeid. If there was danger of the healthy mueous membrane suffering from the eontaet of a fluid only a little more aeid than that destined to be eontinually touehing it, should we not expeet it to have been of sueh a eharaeter as to resist this aetion like the mueous membrane of the stomaeh, instead of being exeited to secrete a fluid of sueh a nature as might lead to its own destruetion? Again, the mueous membrane of the bladder bears very well the contaet of aeid fluids whieh are sometimes injeeted; and patients sometimes for years pass intensely aeid urine, without the seeretion of this exeess of alkaline fluid from the mueous membrane.

201. **Uræmia** is the term applied to that eondition of the system whieh soon follows the retention of exerementitious urinary substanees in the blood. The eondition generally results from long-continued organie disease of the kidneys, but it may depend upon aeute disease. The nervous phenomena are generally eonsidered to depend upon the aeeumulation in the blood of urea, but later researehes have shown that neither urea, earbonate of ammonia, nor nitrate of potash, injeeted into the blood of animals, prove speedily fatal, unless the kidneys be previously extirpated (Hammoud). If, however, the quantity of urea injeeted be very large, death does take plaee. Stannius, on the eontrary, states that urea injeeted into the blood is harmless; and Petroof has injeeted a large quantity into the blood without eausing eoma. Dr. Hammond has shown that the urine, as a whole, is more poisouous than a simple solution of urea. He has proved most eonelusively that Frerieh's notion—that the urea beeame deeomposed into earbonate of ammonia—is erroneous; and Johnson, Riehardson, and others, are of the same opinion. Hoppe fiuds that, in uræmia, the extraetives are inereased to three times and the ereatine to five times the normal amount.

Dr. Riehardson has shown that even water in exeess in the blood will produee symptoms resembling those present in uræmia ("*Clinical Essays*," Vol. I., p. 171); but he agrees with most other observers

in considering that the condition uræmia depends upon the retention of urea in the blood, and its action upon the tissues of the body as a poison.

In considering this question, it must be borne in mind not only that the renal disease has gradually advanced, and that the kidneys, have become almost inefficient, but that most important alterations have been slowly taking place in the blood. Many tissues in the organism have been secondarily affected, and are probably much altered in structure. At present, we are but very imperfectly acquainted with the normal changes occurring in the blood, or with the consequences immediately resulting to the tissues, especially the nervous system, in consequence of the retention of certain excrementitious matters; and we know very little of the remote or immediate effects resulting from certain excrementitious substances not being formed at all. The question is a more difficult one than at first appears, and requires more searching chemical and microscopical investigation than it has yet received. The latest writer on this subject concludes a very elaborate essay thus: "Enfin, cette altération chimique du sang est encore mal définie, et la science attend sur ce point de nouvelles recherches." ("*De L'Urēmie, These,*" par Alfred Fournier, 1863.) At the same time, it is quite certain that the accumulation of urea, and probably other urinary constituents, in the blood, will give rise to uræmia as soon as the proportion reaches a certain amount. This must occur if the formation of these substances proceeds, while, from their damaged state, the kidneys can no longer separate them.

202. **Ammonia.**—Numerous experiments seem to show that in health a small quantity of ammonia escapes in the urine. Neubauer has conclusively proved that certain ammoniacal salts pass through the organism, and may be detected in the urine unchanged. Ammonia, as is well known, is very easily produced by the decomposition of the urea; but it is almost certain that a small quantity passes into the urine from the blood, independently of that derived from this source.

In disease, the quantity of ammonia present in the urine is often so great as to be smelt all over the room in which the patient lies; but in these cases the ammonia arises from the decomposition of the urea after the urine has left the bladder, and in some it is decomposed even while it yet remains in this viscus.

It is doubtful if a large amount of ammonia under any circumstances accumulates in the blood afterwards to be excreted in the urine, as it is probable that, if formed, it would escape more rapidly from the lungs or intestinal canal. The doctrine that the coma occurring as a sequel to many cases of kidney-disease, depended upon the accumulation in the blood of ammonia produced by the decomposition of urea, was originally put forward by Frerichs. In some of these cases of renal coma, ammonia is present in abnormal quantity. In others, neither urea nor ammonia can be discovered in the blood, while sometimes urea can be detected without difficulty.

I have examined the serum in many cases for urea. Half an ounce of blister serum from a man suffering from renal coma yielded ·54 gr. of nitrate of urea. The patient died shortly afterwards, and urea was detected in the blood and in the brain substance. In another instance, it was detected in the serum of a blister from a man who had had one epileptic fit, depending upon renal disease. In the case of a boy, aged 18, who suffered from epileptic fits, I also detected it in blister serum; as well as in eight ounces of serum from a man suffering from acute dropsy of a week's duration; and I might refer to others in which I obtained undoubted evidence of the presence of urea. There are, however, cases of the same character in which I failed to detect urea, or ammonia resulting from its decomposition.

I have several times examined the breath of such patients, without being able to obtain indications of a larger quantity of ammonia than is afforded by healthy persons. I think, therefore, that we must admit that there are many cases of the so called *uræmic poisoning* which have not yet been satisfactorily explained. It may, however, be urged, that in many cases, although ammonia was formed, it might have been rapidly eliminated from the skin or intestinal canal, so as to escape detection. Bernard and Barreswil have performed some experiments which prove that, after extirpation of the kidneys, urea escapes into the intestinal canal in the form of an ammoniacal salt; and they found that it could not be detected in the blood in less than from twenty-four to forty-eight hours after the operation, when the animal had become weak and exhausted.

Dr. Garrod has detected urea in the blood and blister serum of several cases of gout. ("*Med. Chur. Trans.*" 1848). His results have been confirmed by Dr. W. Budd, who has detected urea in the

blister serum, in nine cases of acute gout, in which there was no indication of renal disease. ("*Med. Chur. Trans.*" Vol. XXXVIII., p. 242.)

203. On detecting Urea in the Blood or Serum.—The urea may be detected by concentrating the serum, after adding a few drops of acetic acid, and extracting with strong alcohol, or the fluid may be evaporated to dryness, and the dry residue treated with boiling alcohol. The alcoholic solution is evaporated to dryness, treated with a drop of distilled water, and two or three drops of strong nitric acid allowed to fall into the syrupy solution. If urea be present, crystals of the nitrate of urea are formed, and may be readily distinguished by microscopical examination. Crystals of nitrate of urea are represented in Plate XI., Fig. 55.

204. On detecting Ammonia in the Breath.—The method of examination which Dr. Richardson recommends is the following:—An instrument in the form of a straight breast-pump is employed to breathe through; a drop or two of hydrochloric acid is placed in the bulb, and a perfectly clean slip of microscope glass placed across the trumpet extremity of the tube, and secured by an India-rubber band. The alkali, as it passes over the bulb, combines with the acid, but some of the acid and alkaline vapours pass over together and condense on the microscope glass. As this becomes dry, crystals are formed (Plate XII., Fig. 65). In health, traces of ammonia are always found in this manner.

205. Urea.—From what has been already said with reference to the variations in the proportion of urea secreted, under different circumstances, in a state of health, it will be inferred that, in disease, the quantity of this constituent varies greatly. The total amount formed in a given time may be much greater or less than in health; and the proportion which this substance bears to the other organic constituents varies greatly in different cases.

206. Excess of Urea.—The term "excess of urea" is not applied to those cases in which the total quantity excreted in the twenty-four hours is much greater than in health; but a specimen of urine which yields crystals of nitrate of urea when an equal bulk of nitric acid is added to it in the cold, without having been previously con-

centrated, is said to contain "excess of urea." The quantity of urea dissolved in the fluid is so great, that a nitrate of urea is formed, and crystallises just as if the urine had been concentrated by evaporation. This result may be brought about in several ways. In cases in which but a small quantity of fluid is taken in proportion to the urea to be removed—when an unusually large amount of water escapes by the skin and other emunctories—and in cases in which an unusual amount of urea is *formed* in the organism, we shall frequently find excess of urea in a specimen of the urine.

Dr. Golding Bird has drawn attention to the frequency of the occurrence of excess of urea with oxalate of lime. The quantity of oxalate of lime, however, is in all cases so very small that it is hardly possible to believe that the formation of this substance can be very important. It will be shown that the oxalate is one of the commonest urinary deposits; that it may result from decomposition of urates; that there is no reason for believing it to be indicative of any peculiar diathesis or habit of body. Excess of urea affords no explanation of the presence of oxalate of lime, nor this latter of urea. Each condition may exist without the other. *Cæteris paribus*, we should expect to find oxalate of lime most frequently present in specimens of highly concentrated urine.

Excess of urea is frequently found in the urine of persons suffering from acute febrile attacks. It is very common in cases of acute rheumatism, and is often met with in pneumonia and acute febrile conditions generally. In England, we meet with these cases very frequently; but, on the continent, they appear to be so rare that many authorities seem to doubt the truth of what English observers have stated with regard to this point. Lehmann, I think, states that he had not seen a case in which crystals of nitrate of urea were thrown down upon the addition of nitric acid, without previous concentration.

The amount of urea excreted is often very great. Vogel mentions a case of pyæmia in which 1,235 grains of urea were removed in the course of twenty-four hours. Dr. Parkes obtained as much as 885 grains in a case of typhoid fever. These quantities are very great, if the patients did not exceed the average weight of adult men; but, unfortunately, the weight was not recorded.

Urine containing excess of urea is generally perfectly clear, of rather a dark yellow colour, and of a strong urinous smell. Its

specific gravity is about 1,030, and it contains generally 50 or 60 grains, or more, of solid matter per 1,000. At ordinary temperatures, an aqueous solution must contain at least 60 grains of urea per 1,000, to form crystals of the nitrate upon the addition of nitric acid without previous evaporation; 50 grains of urea per 1,000 hardly gave the slightest precipitate after the lapse of a considerable time. It would seem that the salts, extractive matters, &c., in urine, cause the crystallisation of the nitrate when even a smaller quantity of urea is present. It should be mentioned, that the above experiments were performed in the summer, in very hot weather. In one case, in which the urea readily crystallised on the addition of nitric acid, the urine had a specific gravity of 1,028, and contained—

Analysis 2.

Water	940·18
Solid Matter	59·82
Organic Matter	50·57
Fixed Salts	9·25

Urine containing excess of urea is generally acid, but I received a specimen from Dr. Fergus, of Marlborough, which was alkaline, and contained crystals of triple phosphate. It came from a patient, 18 years old, who was feverish with gastric and biliary disturbance. The urine was high coloured, sp gr. 1·033, and became nearly solid upon the addition of an equal bulk of nitric acid, from the formation of crystals of nitrate of urea. (April, 1862.)

207. **Clinical Observations.**—There are some peculiar and not very common cases in which the urine contains this excess of urea; and at the same time more than the healthy amount is excreted in twenty-four hours. The patient is weak, and grows thin, in spite of taking a considerable quantity of the most nutritious food. He feels languid, and indisposed to take active exercise. In some cases, digestion is impaired; in others, the patient eats well, experiences no pain or uneasiness after food, and perhaps has a good appetite. Sometimes there is lumbar pain. It would seem that much of the nutrient material in the blood, instead of being applied to the nutrition of the tissues, becomes rapidly converted into urea, and is excreted. The waste of the tissues is not properly repaired, and

the patient gets very thin. To refer these symptoms to the existence of a particular diathesis, appears to me no explanation of the nature of the case. The pathology of these remarkable cases has not yet been satisfactorily investigated. Mineral acids, rest, shower-baths, and good air, often do good; but some of these patients are not in the least benefited by remedies, and they continue for years very thin, passing large quantities of highly concentrated urine, while the appetite remains good, and they digest a considerable quantity of nitrogenous foods. In one of these cases, which had resisted the usual plans of treatment, benefit was derived from the use of pepsine,* with diminished quantity of meat, and a larger amount of farinaceous food. The condition often lasts for some years.

208. **Deficiency of Urea.**—In chronic disease of the kidney, the urine is of very low specific gravity, and but a very small proportion of urea is excreted in the twenty-four hours. This arises from the alteration in the gland-structure, and the amount of urea separated may be regarded as a rough indication of the extent of the organ involved. In some cases, the morbid condition affects the whole structure; but in others the greater part of the kidney remains healthy. In the latter case, a fair amount of urea will be excreted; and, although the urine contains albumen, the case may be looked upon as a hopeful one. Sometimes the quantity of urea excreted is very small. A lady suffering from an ovarian tumour only excreted 75 grains of urea in 200 fluidrachms of pale faintly alkaline urine in the course of twenty-four hours. (Thudichum). In a case of cancer of the uterus, under the care of Dr. Farre, only a few drachms of fluid were passed from the bladder during a week; and this contained a small quantity of solid matter, in which no urea was detected.

In certain cases, urea almost entirely disappears from the urine, and is replaced by leucine and tyrosine. Frerichs mentions a case of acute yellow atrophy of the liver, in which only a trace of urea could be detected, while a very large quantity of leucine and tyrosine crystallised from the concentrated urine. ("*Klinik der Leberkrankheiten.*" *Erster band.* *Seite* 221.) In low forms of typhoid

* The pepsine I always use is that prepared, according to a plan I proposed, by Messrs. Bullock & Reynolds, Hanover Street, W. ("*Archives of Medicine*," Vol. I., pp. 269, 316.) *See* also the paragraphs on the treatment of Diabetes.

fever, the urine also frequently yields leucine and tyrosine in considerable quantity.

In a case of chronic yellow wasting, which came under my own notice (F. C., Vol. vi., p. 37), the liver was of a yellow colour, and weighed 1½ lb. The patient was a young woman, age 26. Jaundice had existed for six weeks, but urgent symptoms—delirium and coma—had only supervened a few days before death. Leucine was obtained from the urine by evaporation, but only in small quantity.

209. **Colouring Matter.**—The variation of colour of the urine in disease is a matter of great interest; and, although the causes of the change, and the exact nature of the substances which give rise to the peculiar tints often observed, are not yet understood, still there are many valuable observations connected with this subject, some of which I propose to refer to in this place. The colour of urine depending upon blood corpuscles being suspended in it will be discussed under the head of urinary deposits; and now I shall only refer to colouring matters formed in the body and excreted in *solution* in the urine. It should be observed, that pyrola, sumach, and some other substances, alter the colour of the urine. Dr. Hughes mentions cases of dark pigment occurring in the urine of patients taking iodine. These cases, however, are of course not dependent upon morbid changes in the organism.

The principal substance to which the colour of urine is due is probably derived from the blood corpuscles, which are continually undergoing disintegration. This colouring matter becomes altered under different conditions. Much of it is converted into a colouring matter which is separated in the urine, and termed uræmatine (uraphæin, hæmaphine), which is soluble in ether, and, according to the researches of Dr. Harley, is a resinous body, agreeing in some of its characters with the biliary resins.

It is impossible to estimate directly the quantity of the colouring matter present; but Professor Vogel calculates the proportion by ascertaining how much water may be added to the urine to produce a particular tint, which is arbitrarily fixed as the unit of comparison. The quantity of this substance affords an indication of the activity of the disintegration of the blood-corpuscles. In typhoid fever, and many other conditions, this disintegration takes place to such an extent as to produce an anæmic condition. In many acute diseases,

a very large amount of colouring matter occurs in the urine. Urea is not unfrequently present in excess in pneumonia, typhus fever, peritonitis, acute rheumatism, etc. The formation of the urine-pigment is intimately connected with the action of the liver; and, as is well known in diseases of this organ, the urine is frequently very high coloured. Of course, I am speaking of colour independent of the colouring matter of the bile. The deep colour of the urine in diseases of the liver has been often remarked by physicians practising in India; and quite recently my friend Dr. Payne has made some interesting observations on this point, which will be found in the "*Indian Annals of Medical Science*" (Calcutta, Sept. 4th, 1858). In order to detect the colouring matter, Dr. Payne boils the urine, and then adds a drop of nitric acid. Various shades of colour are produced, but at last the mixture becomes of a ruby red. Deficiency of colouring matter occurs in many cases of anæmia. Sometimes the urine is as pale as water.

Heller's observations upon the colouring matter have been alluded to (§ 112). This observer found more uroxanthine (which may be decomposed into indigo blue or uroglaucine, and indigo red or urrhodine) in the urine of persons suffering from diseases of the serous membranes, of the kidneys, and of the spinal marrow, than in the healthy secretion. Schunk, who first separated indigo blue and indigo red, and showed their identity with Heller's uroglaucine and urrhodine, found as much uroxanthine or indican in healthy as in morbid specimens of urine; and he detected it in the urine of thirty-nine persons out of forty. The quantity of this colouring matter is exceedingly small. Schunk, by working on the urine of two persons for several weeks, only obtained one grain of indigo blue.

My friend Dr. Eade, of Norwich, sent me a specimen of urine containing a deposit of uroglaucine obtained from a man eighty-three years of age. ("*Archives of Medicine*," vol. i., p. 311.) Some of these crystals are represented in Plate XII., Fig. 64; and in Fig. 63 are shown some crystals of indigo. *a*, crystals obtained by sublimation; *b*, larger crystals of the same; *c*, small crystals of indigo in fluid. Fig. 64 contains numerous crystals of uroglaucine from the urine. *a*, small collections of a pale blue colour, like Prussian blue; *b*, a darker mass, formed of small spherical masses; *c*, crystals of uroglaucine, of a deep purple or violet colour.

210. Tests for Uroxanthine.—When sulphuric acid is added to urine containing much uroxanthine, a dark blue colour is produced. The mode of employing this test recommended by Dr. Carter, who has made some important investigations on this subject ("*Edinburgh Medical Journal*," Aug. 1859), is as follows:—Urine is poured into an ordinary test-tube, to the depth of half an inch; one-third of its volume of sulphuric acid, specific gravity 1,830, is then allowed to subside to the lower part by letting it fall gradually down the side of the tube; the acid and urine should then be mixed well together. The colour produced varies from a faint pink or lilac to a deep indigo blue colour.

Is uroxanthine to be considered an ingredient of normal urine? As Schunk found this substance in the urine of thirty-nine healthy persons out of forty, and Dr. Carter recently detected it in the urine of three hundred persons (some suffering from disease, others healthy), we may, I think, regard it as a constituent of healthy urine. Dr. Carter has detected it in the blood of several patients—in fact, in every case in which he sought for it. It was also found in the blood of the ox.

Process. The serum was poured off, and a strong solution of diacetate of lead added to it as long as a precipitate was produced. The mixture was then thrown upon a linen filter, and the filtrate was brought to the boiling-point as rapidly as possible in a small flask, in order to coagulate the albumen that had not been precipitated by the lead salt. The solution was then filtered through paper into a vessel placed in cold water; and, when the liquid was cold, a slight excess of caustic ammonia was added. The deposit thus produced, when collected and slightly washed with water, was of a faint yellowish buff colour. The moist precipitate, upon being treated with excess of concentrated sulphuric acid, developed a distinct red colour, owing to the formation of indigo red. The colour was taken up by ether, after the acid had been neutralised by ammonia. The oxide of lead precipitate, from an ounce and a half of blood-serum from a man, forty-three years of age, suffering from acute pleurisy, struck with the acid a distinct lavender colour, which in half an hour passed into a deep red purple. ("*On Indican in the Blood and Urine*," by J. A. Carter, M.D.; "*Edinburgh Medical Journal*," August, 1859.)

Fig. 61.

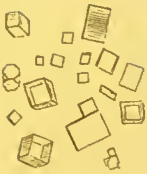

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Fig. 62.

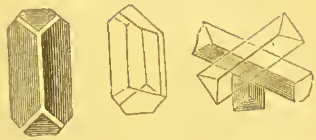

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Fig. 63.

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Fig. 64.

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Fig. 65.

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211. Colouring Matter of the Blood.—The colouring matter of the blood-corpuscles may be present in urine without any corpuscles. In many cases, owing to the rapid disintegration of blood-corpuscles, the serum is highly coloured, and the dissolved colouring matter is excreted by the kidneys. Blood may escape from the vessels into the tubes of the kidney, the corpuscles may gradually become disintegrated, and the colouring matter be dissolved; *hæmatoglobuline* coagulates at a temperature of about 200°, while *albumen* is precipitated at a temperature a little above 140°. In this manner these substances may be distinguished.

There can be little doubt that both the colouring matter of the bile and of the urine are derived from that of the blood-corpuscles. The precise manner in which the change is accomplished has not yet been demonstrated, but it is not improbable that careful observations upon the urine in disease would lead to a solution of this question. That bile-acids and their salts were powerful solvents of blood-corpuscles, was long ago proved by Hühnefield, Plattner, and Simon; and it has lately been shown by Kühne that, by the action of the colourless biliary acids or their salts upon the blood-corpuscles, bile-colouring matter is produced. The bile-acids themselves are not converted into the colouring matter, as Frerichs held; for they pass through the system unchanged. Now, in certain cases where these processes are deranged, it is very probable that the blood-corpuscles are disintegrated in abnormal quantity, and rapidly converted into pigment, which escapes in the urine. The complicated mutual reactions which would ensue when varying proportions of biliary acids, hæmatine, and oxygen, are presented to each other in the living blood, would fully account for the different characters and tints which the colouring matters in urine assume in various cases. Professor Vogel alludes to a case in which the colour of the urine became very dark after the inhalation of arseniuretted hydrogen. Some experiments were made upon a dog, and it was found that the dark colour was due to the disintegration of blood-corpuscles. Albumen was present, but no blood-corpuscles could be detected. A similar disintegration of blood-corpuscles seems to take place in typhoid fever, and in several other diseases.

212. Black Pigment.—Dr. Marcet describes a black pigment which was present in the urine of a child. After the addition of an

acid, some black flocculi were deposited. Professor Dulk gives a case in which a black deposit was separated from the urine by filtration. Other examples are recorded by Dr. Hughes. In three of these cases, creasote had been taken internally; and in two, tar had been applied externally. In one case, a dense black precipitate was thrown down by heat and nitric acid, which was examined by Dr. Odling, who found that, by exposure, it became converted into indigo blue. He draws attention to the close alliance between indigo and the creasote series of compounds, and suggests that, in the above cases, it was derived from the tar or creasote. (Quoted in Dr. Golding Bird's work, fifth edition, edited by Dr. Birkett.)

213. **Uric Acid and Urates** are present in certain proportion in healthy urine, but in disease a large increase is very frequently observed. These substances form urinary deposits, either from existing in too large a proportion to be dissolved in the urine when cold, or, as is probably the case in the majority of instances, from the development of an acid in the urine, which causes them to be precipitated from their solutions. The microscopical characters of these bodies will be considered under the head of urinary deposits. In many acute febrile diseases, the proportion of uric acid is increased, and the period of resolution of the inflammation is marked by diminished frequency of the pulse and respiration, by a fall in the temperature, by free perspiration, and by a very abundant deposit of urates. In health, from 5 to 8 grains of uric acid are excreted in twenty-four hours; but, in some acute diseases, the proportion may amount to twenty grains. In a case of fever, Dr. Parkes found that 17·28 grains of uric acid were excreted in twenty-four hours. Dr. Sansom has estimated the quantity of uric acid in 1,000 grains of the morning urine in health and several cases of disease. The results are as follows:—

	Grains.
Health	·250
Acute Gout	·830
Acute Rheumatism	·802
Heart Disease	.711
Erysipelas	·679
Phosphatic Urine	·140
Chronic Gout	·120
Excessive Debility	·078

Urate of soda is very readily caused to deposit crystals of uric acid. If the amorphous deposit be merely dissolved by warming the urine, the urate often becomes decomposed; and, as the solution cools, crystals of uric acid are deposited. In some cases, the quantity of uric acid held in solution is so great that, upon the addition of a drop of nitric acid to the urine, an abundant amorphous precipitate, exactly resembling albumen, is formed. Such a precipitate has many times been mistaken for albumen (see "*Albuminous Urine*"), and, even if examined under the microscope immediately after it is formed, its nature cannot be made out; but if it be allowed to stand for some time, the amorphous particles gradually increase in size, and assume the well-known crystalline form of uric acid. The instances in which I have met with urine exhibiting these characters have almost all been cases of liver-disease. Although the reaction is acid, no precipitate takes place upon the application of heat, which at once distinguishes urine of this character from albuminous urine.

The presence of an increased quantity of uric acid in the urine shows that more of this substance or its salts is formed in the blood than in health. It would appear that, in consequence of certain conditions, a large proportion of the uric acid resulting from the disintegration of albuminous substances is not further oxidised and converted into urea, but combines with ammonia, soda, or lime, forming urates of these bases.

In gout, the presence of uric acid in the blood has been shown to be constant by Dr. Garrod, who considers that in this condition "the kidneys lose, to some extent, their power of excreting uric acid," although they eliminate urea as in health. ("*The Nature and Treatment of Gout*," p. 167.) *During* the attack there is less in the urine than in health; but, *after* it is over, a large quantity of uric acid and urates are often carried off from the system in the urine.

214. Treatment of Cases in which the Uric Acid is in Excess.—In cases characterised by a tendency to the formation of much uric acid, the principal objects to be attained by treatment are, to favour the further oxidation of the uric acid formed, and to promote its solution and elimination from the blood as rapidly as possible. Good air and moderate exercise, with attention to the

action of the skin, will fulfil the first object; and the solution and elimination of the urates will be encouraged by giving alkalies in solution in a considerable quantity of water.

The satisfactory change which, in chronic gouty and rheumatic cases frequently ensues from following some of the much vaunted "systems," or going through a course of bathing in Germany or elsewhere, obviously arises from the increased action of the skin, and the improvement of the health generally, effected by the exercise, good air, simple diet, and temperance, wisely enforced in the establishments. If patients could be induced to retire to a pleasant part of the country, where they could take moderate exercise and be free from mental anxiety, meet with agreeable society, live regularly, take small doses of alkalies, and soak themselves for an hour or two a day in warm water in which some carbonate of soda had been dissolved, they would receive as great benefit as by travelling hundreds of miles away, and at much less trouble and expense. I am convinced that there are many patients who would prefer to carry out such a simple plan, rather than submit themselves to all the useless routine and absurd formalities involved in many of the professed universal systems, such as homœopathy, hydropathy, etc., which cannot but be extremely offensive to their common sense,—while they are claimed as converts and supporters of doctrines which they do not really believe in. There are many who, for the sake of the advantage they derive from the regular system of living, air, exercise, etc., express no disbelief in doctrines and propositions which they probably feel to be absurd, and which a little reflection must prove to be false.

In all such cases, the nature of the derangement of the physiological processes should be carefully considered before any plan of treatment is adopted. We must ascertain in what points the condition differs from a healthy state, and then consider how the deranged actions may be restored. It is obviously quite useless to attempt to relieve the patient by giving drugs, without enforcing attention to all the circumstances which are likely to improve the health. Neither will it be wise to attempt to treat the case as if the presence of the uric acid deposit were the most important symptom, for the reasons I referred to when considering the subject of diathesis.